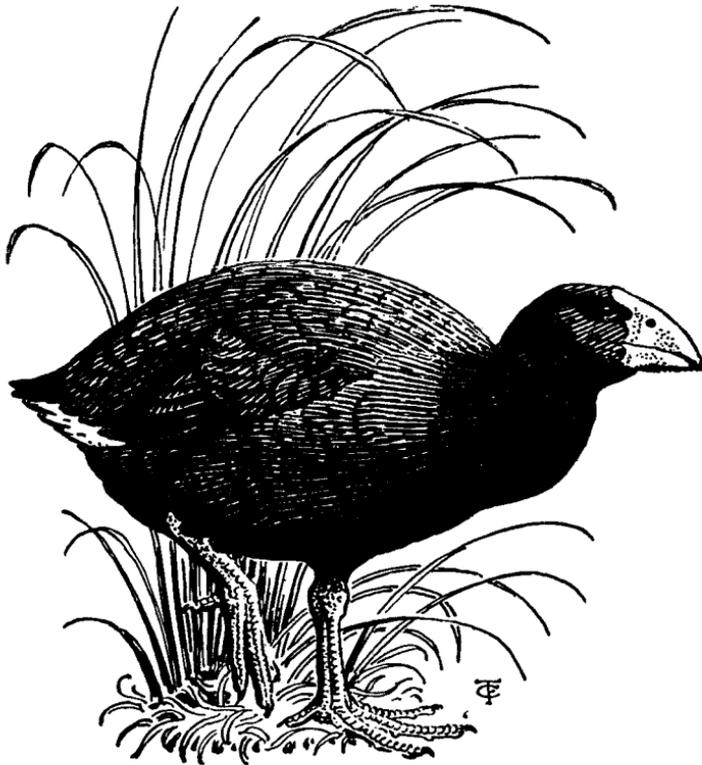


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COMPARATIVE BIOLOGY OF THE BURROWING PETRELS OF THE CROZET ISLANDS

By P. JOUVENTIN, J. -L. MOUGIN, J. -C. STAHL
and H. WEIMERSKIRCH

ABSTRACT

This paper presents, as well as some earlier data, the results of a study of the burrowing petrels of the Crozet Islands (South Indian Ocean) made during the East Island expedition of September 1981 to February 1982.

The 16 petrels are discussed and analysed in the following taxonomic groups: 4 gadfly petrels, 5 prions, 2 *Procellaria* petrels, 3 storm petrels and 2 diving petrels. For each group, biometric data and the breeding biology of each species are given. The timing of events (first return to land, laying, hatching, fledging), nest reoccupation, incubation schedule, chick growth and chick-feeding pattern were the main study topics.

Abundance cycles during pairing, temporary egg desertions, nest selection, comparison with other localities and particularly ecological segregation of the petrels are discussed.

INTRODUCTION

The Crozet Islands, discovered in 1772 by the French navigator Nicolas Marion-Dufresne, lie in the Indian Ocean between longitudes 50°00' and 52°30' E and latitudes 45°50' and 46°30' S.

A recent study (Gamberoni *et al.* 1982) showed that the Antarctic Convergence is displaced northwards in the Crozet - Kerguelen region by the shelves of these island groups. The Crozet Islands are more than 300 km south of the Polar Front but north of the limit of the subsurface temperature minimum between 48° and 49° S. Thus, the chief hydrological characteristic of this region is the limited extent of subantarctic waters because the Antarctic and Subtropical Convergences are very close together (43° and 41° respectively).

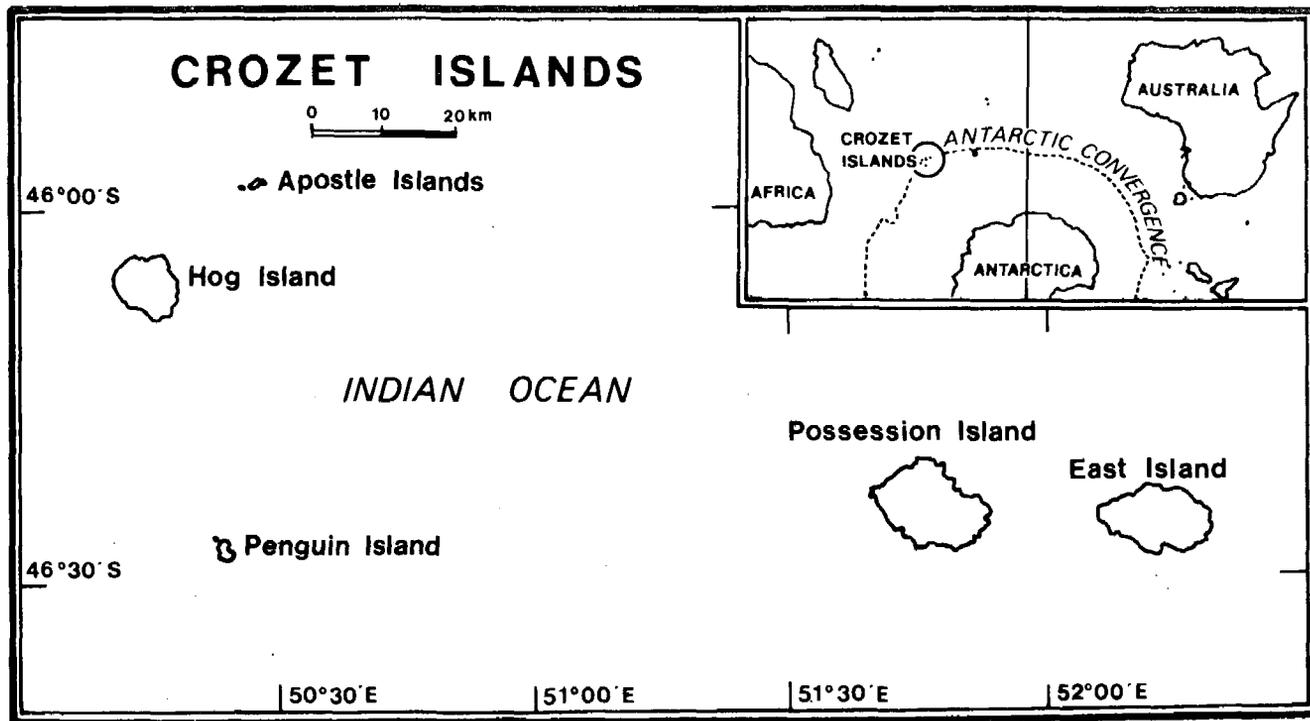


FIGURE 1 — Location and map of the Crozet Islands

The Crozet Islands are scattered over about 150 km east to west and have an estimated total land area of about 500 km². There are two groups of islands (Fig. 1); to the west, Hog Island, Penguin Island and Apostle Islands, and to the east, Possession Island and East Island. The islands are volcanic in origin and are small (the largest, Possession Island, is 18 km on its longest side), but the topography is complex and rises to quite a high altitude. The highest point is 1050 m on East Island. The coastline alternates between cliffs and beaches of sand or boulders. The interior consists of large glacial valleys separated by rocky ridges or high plateaus. The tundra-type vegetation (no trees occur on the Crozets) does not extend higher than 300 m a.s.l.

The climate is severe, even for the "roaring forties". The temperatures are cold, the mean annual temperature being + 4.6°C. There is a small variation in temperature between the warmest month (February, + 7.7°C) and the coldest (September, + 2.8°C), but the climate is characterised by violent winds, which have a mean annual speed of 12 m/s (43 km/h) and a maximum of 70 m/s (252 km/h). For example, in 1980 the wind blew at speeds of more than 115 km/h on 93 days. Sunshine hours are low overall (a monthly mean of 103 hours) and rainfall is high (2470 mm per annum). During winter, snowfalls are frequent but there is no permanent snow on the islands.

We have shown elsewhere (Jouventin *et al.* 1984) that the Crozet Islands shelter a rich seabird community. East Island has the most birds of the group. Of the 34 seabird species breeding on the Crozets, 32 are on East Island, which lacks introduced predators (cats and rats). This island is the breeding ground of 23 procellariiformes (5 albatrosses, 13 procellariids, 3 storm petrels and 2 diving petrels) compared with 15 on Possession Island, 8 on Hog Island, 18 on Penguin Island and 15 on Apostle Islands. Of these 23 species, 15 nest in burrows. The only burrowing species of the Crozets missing on East Island is the White-headed Petrel (*Pterodroma lessonii*), which nests only on Possession Island. Studies of burrowing petrels of the Crozet group are therefore best done on East Island.

A study of this kind was lacking. The whole breeding cycle of some of these petrels — *Pterodroma brevirostris* (Mougin 1969), *P. lessonii* (Barré 1976), *Procellaria aequinoctialis* (Mougin 1970, 1971), and *Procellaria cinerea* (Barrat 1974, Despin 1976) — had been studied on Possession Island. Partial studies on most of the burrowing petrels had resulted from summer expeditions to East Island (Despin *et al.* 1972) and Hog Island (Derenne *et al.* 1976, Derenne & Mougin 1976) for limited periods of time. A complete study of all the burrowing petrels had still to be done, and we attempted this on East Island from September 1981 to March 1982.

METHODS

We marked occupied burrows during pairing of the birds as soon as possible after the adults returned to land. We judged this by listening to the diurnal and nocturnal vocal activity of the pairs and by closing the entrances of burrows suspected of occupation and seeing if they were reopened by the next morning. For monitoring, we dug observation windows above the nesting chamber of each burrow and rearranged nests among rocks. We marked study

nests and, whenever possible, ringed both birds in each pair on a different leg to simplify identification. For the more timid species we occasionally ringed only one of the pair or marked them with paint to reduce handling.

To compare the growth of chicks of the various species, we measured and weighed them at 3-day intervals to calculate the mean growth-rates. To study chick feeding we weighed chicks daily. An increase in weight or stable weight between two weighings was considered to represent a feeding. For each nest we divided the number of nights with chick feeding by the total number of nights studied to get the frequency of feedings, F . To calculate the sojourn at sea per adult we have used the formula

$$1 - F = (1 - p)^2$$

where p is the probability of a visit to the nest by an adult. We draw from this that

$$p = 1 - \sqrt{1 - F}$$

The actual number of visits by the parents during the study period is then equal to $2pn$, n being the total number of nights studied. Finally, the interval between two visits by the same adult is equal to $\frac{1}{p}$.

GADFLY PETRELS

On the Crozet Islands, the genus *Pterodroma* is represented by four species, the Great-winged Petrel (*P. macroptera*), the White-headed Petrel (*P. lessonii*), the Kerguelen Petrel (*P. brevirostris*) and the Soft-plumaged Petrel (*P. mollis*).

Table 1 shows the measurements of the birds from this locality (partly from Prévost 1970, Despin *et al.* 1972 and Barré 1976), and Table 2 shows the chronology of their breeding cycles (partly from Warham 1956, Mougín 1969, Despin *et al.* 1972, Barré 1976, Imber 1976).

The White-headed Petrel and the Soft-plumaged Petrel are summer breeders. White-headed Petrels occupy their colonies from September to May, whereas Soft-plumaged Petrels breed from September to April. The rather long breeding cycle of the Great-winged Petrel is centred on the winter season, its return to land being in February. Fledging occurs from October to December. Between mid-December and the beginning of February, the adults are absent from their colonies. The breeding cycle of the Kerguelen Petrel, which lasts a little less than 6 months, is the shortest of the four species. It begins in August, before the end of winter, and ends in February.

During its long non-breeding season, the Kerguelen Petrel visits its colonies frequently (Mougín 1969). Between the first returns to land and laying, pairing is long for the gadfly petrels (Table 2), except for the Kerguelen Petrel.

Reoccupation of burrows

Soft-plumaged Petrel: 32 burrows were inspected daily. Occupation of burrows was low at the end of September but increased progressively during October, reaching a maximum in the last 10 days of the month. Thereafter, it diminished up to the beginning of December, when the first layings began (Fig. 2). The occupation of burrows increased regularly between the 80th and 51st days before laying, attaining a maximum between the 50th and 41st days.

TABLE 1 —Weights (g) and measurements (mm) of *Pterodroma* species

	<i>P. macroptera</i>	<i>P. lessonii</i>	<i>P. brevirostris</i>	<i>P. mollis</i>
Weight				
Mean \pm S.D.	560 \pm 58	770 \pm 15	331 \pm 40	302 \pm 23
Range (n)	455-680(28)	750-780(3)	210-400(29)	245-360(72)
Wing				
Mean \pm S.D.	306 \pm 7	309	259 \pm 8	253 \pm 5
Range (n)	293-320(29)	305-319(5)	231-275(33)	238-265(76)
Culmen				
Mean \pm S.D.	36.4 \pm 1.2	38.5	27.0 \pm 1.4	28.5 \pm 1.0
Range (n)	33.5-38.8(29)	37.8-39.5(5)	24.5-29.0(33)	25.0-31.8(76)
Tarsus				
Mean \pm S.D.	43.8 \pm 1.4	45.9	38.5 \pm 1.5	35.8 \pm 1.0
Range (n)	41.2-48.0(29)	43.0-48.5(5)	35.5-41.0(33)	33.5-38.0(76)

TABLE 2 —Timing and duration of events during the breeding cycle of *Pterodroma* species. Values in brackets indicate estimates from data available in other localities.

	<i>P. macroptera</i>	<i>P. lessonii</i>	<i>P. brevirostris</i>	<i>P. mollis</i>
Visits observed during the post breeding period	No	No	Yes	No
First return on land	7 feb 71 15 feb 82	sep	9-28 aug 68	before 20 sep 81
Length of pre-laying period (days)	(75)	80	53 range 43-63(6)	\geq 88
Laying period			10 oct 68 \pm 1 15 oct 81 \pm 6	16 dec 81 \pm 6
Mean \pm S.D.			9-13 oct 68(9)	9-28 dec (17)
Range (n)	(25 apr - 10 jun)	late nov - early dec	2-25 oct 81(17)	
Period from laying to hatching (days)				
Mean \pm S.D.		60	58.7 \pm 5.7	52.0 \pm 2.6
Range (n)		(1)	54-65(3)	49-55 (6)
Real incubation period (days)				
Mean \pm S.D.			49.3 \pm 1.8	50.2 \pm 0.8
Range (n)			47-51(7)	49-51(6)
Hatching period				
Mean \pm S.D.	(20 jun.-late jul.)	late jan - early feb	28 nov 68 \pm 2 10 dec 81 \pm 6 27-30 nov 68(4)	7 feb 82 \pm 5
Range (n)			30 nov -17 dec 81(7)	2-16 feb (7)
Fledging period (days)		>100	62(61-63)(2)	
Departure of fledglings from the colony				
Mean \pm S.D.	4 nov 81 \pm 14	1-15 may	27-29 jan 68	
Range (n)	16 oct -11 dec (35)		23 jan -3 feb 71 29 jan -18 feb 82	

Number of occupied nests (%)

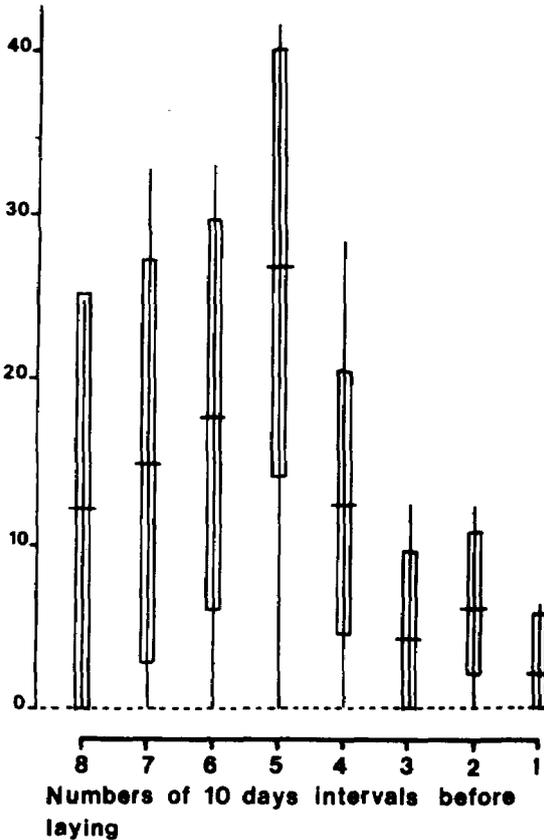


FIGURE 2 — Nest attendance by *Pterodroma mollis* before laying on Crozet

It then diminished rapidly for 10 days, and remained low for the month before laying. Individual visits lasted 1.3 ± 0.7 days ($n=153$, range 1-6 days), 79.1% of them lasting not more than 1 day.

Kerguelen Petrel: A high diurnal occupation of the colonies on Possession Island was noted at the end of August: 33.3% of nests during the second 10-day period of the month and 10.2% during the third 10-day period were visited by at least one adult each day. Of the total number of visits 86.4% lasted not more than 1 day and 13.6% lasted 2 days (mean 1.1 ± 0.4 days). In September and early October, visits became fewer or strictly nocturnal with no birds observed during the day in the 11 nests studied. It was the same on East Island during the last days of pairing. Of the 16 nests monitored before laying (5-28 days of observation), nest visits occurred on only 2 out of the total of 285 nest-days, or 0.7%. Thus, this species has a long prelaying exodus by both sexes.

Activity of non-breeders

In the Soft-plumaged Petrel, non-breeders exceeded breeders. Out of 32 burrows studied, only 36 of the total of 88 banded birds bred. That is, 59.1% of the birds were non-breeders. Of the 88 birds, 82 (93.2%) did not use more than one burrow throughout courtship and 6 (6.8%) used two. Each of the 32 burrows studied was visited by 2.94 ± 1.64 birds (range 1-7). Some nests of the Soft-plumaged Petrel were more frequented than others; these were the ones in which eggs were subsequently laid. The 15 burrows in which no laying occurred were frequented by 2.07 ± 1.33 birds (range 1-5), whereas the 17 burrows where the petrels did lay were frequented by 3.71 ± 1.53 birds (range 2-7), the two values being significantly different ($t=2.82$; $p < 0.01$).

Nest occupation rate was higher in the Kerguelen Petrel. On East Island, 17 eggs were laid in 23 burrows (73.9%), and on Possession Island in 1968, 9 eggs were laid in 11 occupied burrows (82%) (Mougin 1969).

Most Soft-plumaged Petrels were faithful to one partner throughout courtship in spite of an enormous abundance of birds. For 64 paired birds observed at this time, 61 (95.3%) kept the same partner, 2 (3.1%) courted two partners in succession and only 1 (1.6%) courted three.

Laying

At the end of the prelaying exodus, most of the females came ashore only very briefly. They first returned on the night of laying (94% of females) and only 6% first returned on the night before the night of laying (17 birds).

The laying dates for gadfly petrels on Crozet are given in Table 2. For most, the laying period was short. It lasted 24 days (17 layings) for the Kerguelen Petrel on East Island in 1981, 5 days (9 layings) for the same species on Possession Island in 1968 (Mougin 1969), and 20 days (17 layings) for the Soft-plumaged Petrel on East Island. For *Pterodroma lessonii* on Possession Island, the laying period lasted from 21 November to 12 December (Barré 1976). Data are lacking for the Great-winged Petrel but results from New Zealand (Imber 1976) and the fledging period on East Island suggest that the laying period could last 5-6 weeks.

Egg measurements of gadfly petrels from Crozet are given in Table 3. The Kerguelen Petrel eggs and those of the Soft-plumaged Petrel are indistinguishable by their weight and volume but differ in shape, the eggs

TABLE 3 —Weights (g) and dimensions (mm) of eggs of *Pterodroma* species

	<i>P. lessonii</i>	<i>P. brevirostris</i>	<i>P. mollis</i>
Weight			
Mean \pm S.D.	99	55.5 \pm 1.9	57.1 \pm 3.5
Range (n)	93-105 (2)	54-59 (8)	52-67 (22)
Length			
Mean \pm S.D.	70.3 \pm 1.0	56.8 \pm 1.8	59.4 \pm 1.9
Range (n)	69.5-71.4 (3)	53.7-60.5 (22)	55.0-63.0 (36)
Breadth			
Mean \pm S.D.	51.7 \pm 1.5	43.9 \pm 1.2	42.8 \pm 1.2
Range (n)	50.0-52.8 (3)	41.2-46.8 (22)	40.0-45.2 (36)

of *P. mollis* being more elongated than those of *P. brevirostris*. The ratio of egg weight to adult weight is 12.9% in *P. lessonii*, 16.8% in *P. brevirostris* and 18.9% in *P. mollis*. We do not have the same data for *P. macroptera*, although, if these are similar to those in New Zealand, the ratio would be 15.5% (Imber 1976).

Incubation

Incubation shifts were studied only for the Kerguelen Petrel and the Soft-plumaged Petrel (Tables 4 and 5, Fig. 3). Shifts were long in both species (average 9-10 days) except for the first shift of the female. As hatching approached, these shifts shortened for the Kerguelen Petrel. In both species, incubation is divided into five or six shifts. The female does more numerous and shorter shifts than the male, but the two sexes incubate for about the same time. Table 5 shows that small differences can exist from year to year in the same species, but they are not significant.

Temporary egg desertions during incubation were particularly frequent for the Kerguelen Petrel on East Island in 1981-82. They were especially noticeable at the beginning of incubation (at the end of the female's first shift) when the return of the males was not synchronous. Thereafter desertions were much shorter and fewer. The egg's resistance to low temperatures for long periods is remarkable: 9 days on average for three eggs that hatched. These temporary desertions are not constant for the Kerguelen Petrel and did not occur in 1968 on Possession Island (Mougin 1969). However, they were much less frequent in 1981-82 on East Island for Soft-plumaged Petrel than for Kerguelen Petrel: of six eggs that hatched, three were deserted once for a maximum of four days.

Thus, the Kerguelen Petrel's sojourns at sea were long during the 1981-1982 incubation, the incubation shifts for both sexes were long, and there were numerous desertions of the egg. The sojourns for the Soft-plumaged Petrel were not as long (11 days average) as for the Kerguelen Petrel (13 days).

The hatching dates of gadfly petrels from Crozet are given in Table 2. Due to the repeated egg desertions during incubation in 1981, hatching for the Kerguelen Petrel was later than in 1968 (Mougin 1969). This was also true for the Soft-plumaged Petrel, the hatching period in 1981-1982 being 2-16 February compared with 21 January-8 February 11 years before (Despin *et al.* 1972).

Incubation in three Kerguelen Petrel nests lasted for a mean of 58.7 days (54-65 days). These eggs were deserted for a total of 9.0 days (4-14 days). If we subtract one figure from the other, we get an actual incubation mean length of 49.7 (48-51) days. The figure obtained in 1968 on four eggs from Possession Island, 49.0 (47-51) days (Mougin 1969), was very similar. The same was true for six Soft-plumaged Petrel nests where the total apparent incubation length was 52.0 (49-55) days. After subtracting 1.8 days of desertion time, we get the actual incubation mean length of 50.2 (49-51) days. The incubation length for the White-headed Petrel on Crozet is 60 days (Barré 1976) but is not known for the Great-winged Petrel. Imber (1976) showed 54.6 (53-57) days to be the average incubation length for this species in New Zealand.

TABLE 4 — Incubating shifts and egg desertions in *Pterodroma brevirostris* and *P. mollis*

	Length of stay in burrow (days)		Length of desertion (days)		Desertion frequency (per cent)	
	Pterodroma		Pterodroma		Pterodroma	
	<i>brevirostris</i>	<i>mollis</i>	<i>brevirostris</i>	<i>mollis</i>	<i>brevirostris</i>	<i>mollis</i>
First shift (♀)						
Mean ± S.D.	4.6 ± 3.4	2.3 ± 1.6	4.3 ± 4.8	1.2 ± 1.8	67	33
Range	(0-9)	(0.5-5)	(0-11)	(0-4)		
Second shift (♂)						
Mean ± S.D.	13.9 ± 3.6	12.5 ± 1.6	1.7 ± 2.1	0	67	0
Range	(10-21)	(11-14)	(0-4)			
Third shift (♀)						
Mean ± S.D.	13.7 ± 2.5	12.8 ± 1.7	1.0 ± 1.7	0.7 ± 1.6	33	17
Range	(11-16)	(10-15)	(0-3)	(0-4)		
Fourth shift (♂)						
Mean ± S.D.	8.3 ± 2.0	12.5 ± 2.1	0.5 ± 1.2	0	17	0
Range	(7-12)	(10-15)	(0-3)			
Fifth shift (♀)						
Mean ± S.D.	7.3 ± 2.9	11.0 ± 1.3	0	0	0	0
Range	(4-9)	(10-13)				

TABLE 5 — Incubation schedule in *Pterodroma brevirostris* and *P. mollis*

		P. brevirostris		P. mollis
		1981-1982	1968-1969	1981-1982
INCUBATION				
Mean length of a shift (days)				
both sexes	mean ± S.D.	9.3 ± 4.1	10.1 ± 4.4	9.9 ± 4.6
	range (n)	1-16 (16)	2-20 (30)	0.5-15 (31)
male	mean ± S.D.	10.1 ± 3.3	12.5 ± 3.6	11.6 ± 3.6
	range (n)	7-15 (7)	7-20 (12)	1-15 (13)
female	mean ± S.D.	8.7 ± 4.7	8.5 ± 4.3	8.7 ± 5.0
	range (n)	1-16 (9)	2-17 (18)	0.5-15 (18)
DESERTION				
Mean number of periods per nest				
	mean ± S.D.	2.0 ± 1.0	-	0.5 ± 0.5
	range (n)	1-3 (3)		0-1 (6)
Total length per nest (days)				
	mean ± S.D.	9.0 ± 5.0	-	1.8 ± 2.0
	range (n)	4-14 (3)		0-4 (6)
Mean length of a period (days)				
	mean ± S.D.	4.5 ± 3.3	-	3.7 ± 0.6
	range (n)	2-11 (6)		3-4 (3)
Frequency of nest-reliefs with desertion (per cent)				
	mean ± S.D.	46.7 ± 25.7	-	11.7 ± 12.9
	range (n)	25.0-75.0 (3)		0-25.0 (6)
STAYS AT SEA				
Mean length (days)				
both sexes	mean ± S.D.	12.7 ± 5.5	10.1 ± 4.4	11.0 ± 4.5
	range (n)	4-22 (16)	2-20 (30)	0.5-17 (30)
male	mean ± S.D.	11.7 ± 5.1	8.5 ± 4.3	9.3 ± 4.9
	range (n)	4-20 (9)	2-17 (18)	0.5-17 (18)
female	mean ± S.D.	14.0 ± 6.1	12.5 ± 3.6	13.4 ± 2.2
	range (n)	8-22 (7)	7-20 (12)	10-17 (12)

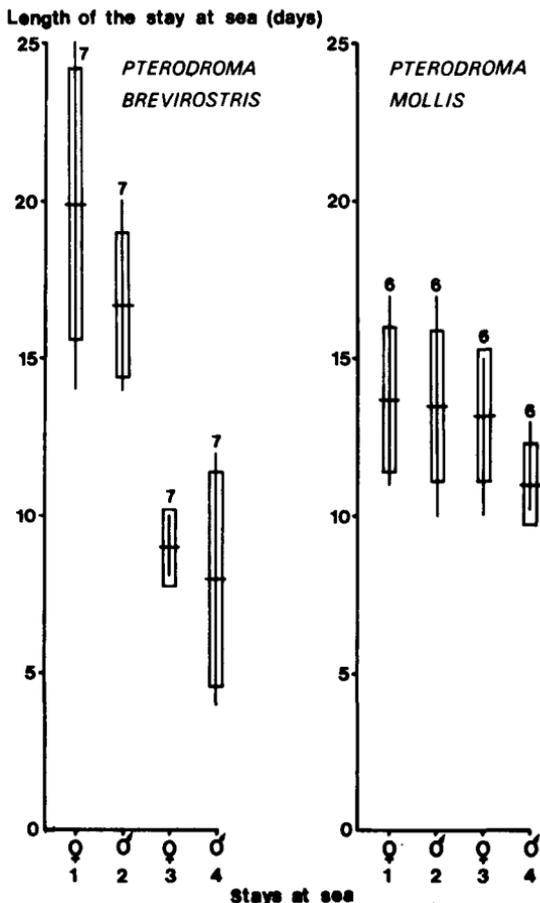


FIGURE 3 — Duration of sojourns at sea in *Pterodroma brevirostris* and *Pterodroma mollis* during each incubation shift. Mean \pm standard deviation, range and sample size

These gadfly petrel chicks were able to survive without the additional warmth of a parent within 48 hours after hatching. This is called *thermic emancipation*.

Chick growth

Weight gain and growth of chicks are given in Fig. 4-9 and in Table 6. Because of the timing of our visit we missed the end of growth of the Soft-plumaged Petrel and the beginning of growth of the Great-winged Petrel. The Soft-plumaged Petrel was monitored for the first month after hatching and the Great-winged Petrel for the last two months of its stay on land. Only the Kerguelen Petrel was studied from hatching to fledging. The White-headed Petrel had already been studied by Barré (1976).

TABLE 6 — Weight growth in *Pterodroma brevirostris* and *P. macroptera* chicks

	<i>P. macroptera</i>	<i>P. brevirostris</i>	
		1981-1982	1970-1971
<u>Weight at birth</u>			
Weight (g)		42.4 ±21.8	
Mean ±S.D.		45-58(4)	
Range (n)		12.8	
Percent adult weight			
<u>Maximum weight</u>			
Weight (g)	653 ±99	410 ±68	440
Mean ±S.D.	470-870(15)	340-475(3)	385-460
Range (n)	117	124	133
Percent adult weight			
<u>Age at peak weight (days)</u>			
Mean ±S.D.	81 ±15	43 ±5	52
Range (n)	57-111(15)	38-48(3)	
<u>Weight at fledging</u>			
Weight (g)	461 ±77	233	310
Mean ±S.D.	305-570(15)	221-245(2)	220-380
Range (n)	82	70	94
Percent adult weight			

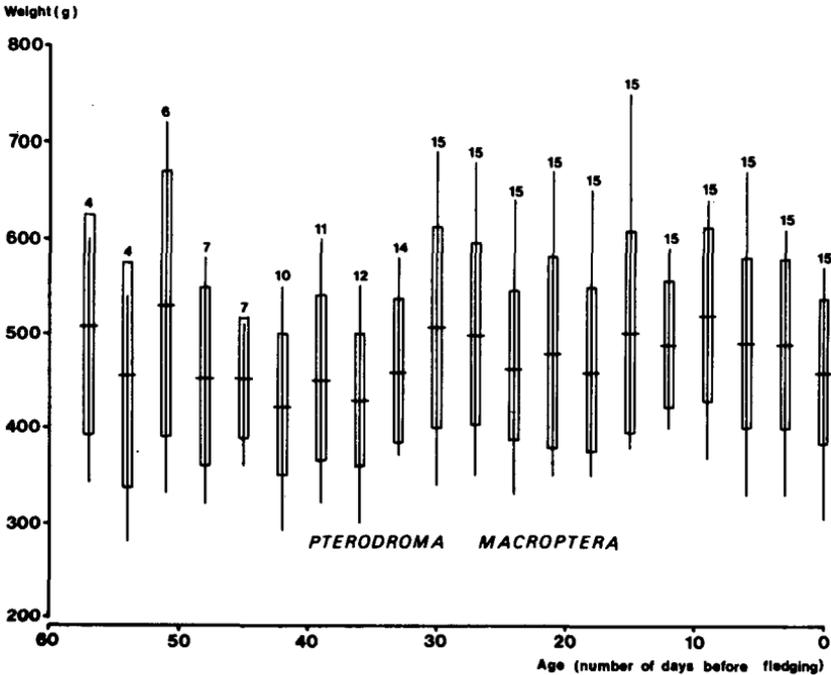


FIGURE 4 — Weight increase in *Pterodroma macroptera* chicks. Mean ± standard deviation, range and sample size

There were two periods in weight growth. The rate of weight gain for the Kerguelen Petrel in three-day periods was $26.5 \pm 18.5\%$ for the first 15 days after hatching and $13.8 \pm 14.9\%$ for the second. For the Soft-plumaged Petrel it was $20.1 \pm 19.2\%$ and $10.8 \pm 9.7\%$. When the Great-winged Petrel and Kerguelen Petrel chicks were two-thirds of the way to fledging, they weighed 20% more than the adults. In the last third of growth the Kerguelen Petrel chicks lost 30-40% of their maximum weight at a rate of decrease of $4.1 \pm 8.7\%$. At fledging the chicks weighed 70 - 80% of the adult weight.

These results vary from year to year. Table 6 shows that the maximum weight and fledging weight for the Kerguelen Petrel were far less in 1981-1982 than 11 years before (Despin *et al.* 1972).

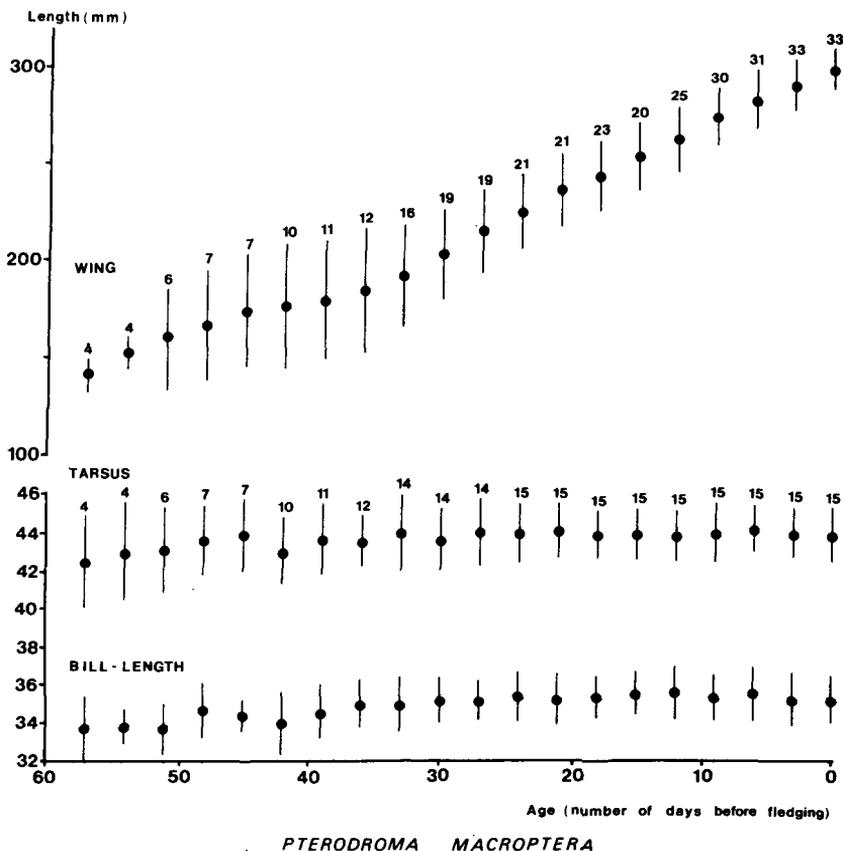


FIGURE 5 — Growth of wing, tarsus and bill length in *Pterodroma macroptera* chicks. Mean \pm standard deviation and sample size

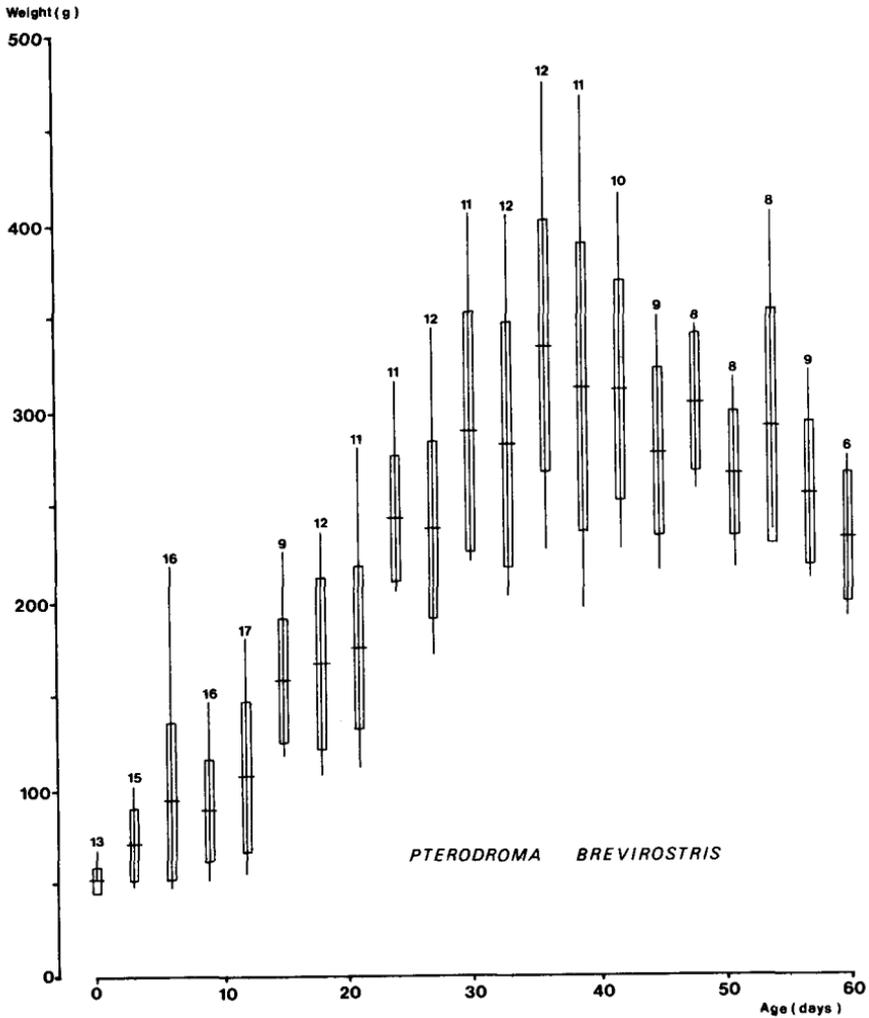


FIGURE 6 — Weight increase in *Pterodroma brevirostris* chicks. Mean \pm standard deviation, range and sample size

The growth of the Great-winged Petrel was slightly different. Maximum weight was followed by a weight loss 37 ± 15 days before fledging. Variation between individuals was considerable, with periods of weight loss lasting 7-61 days for the 15 chicks studied. Some chicks gained weight while others were losing it, but the mean weight of our 15 chicks remained constant during the last two months of growth (Fig. 4). As usual, wing growth occurred in two stages. Before the appearance of the primaries it was slow, the average rate of increase in three-day periods reaching $5.2 \pm 4.3\%$ for the Kerguelen Petrel and $5.5 \pm 3.2\%$ for the Soft-plumaged Petrel. With the appearance of the primaries, it was more rapid and nearly constant until fledging, the rate of increase being $14.5 \pm 8.3\%$ for the Kerguelen Petrel, $11.5 \pm 8.3\%$ for the Soft-plumaged Petrel and only $4.1 \pm 17\%$ for the Great-winged Petrel. Adult size was not always reached by the time the chicks fledged.

The culmen and tarsus also developed in two stages, rapidly at first and then slowing down or even totally stopping as in the Great-winged Petrel for the last two months in the nest. All reached adult measurements by the time they fledged.

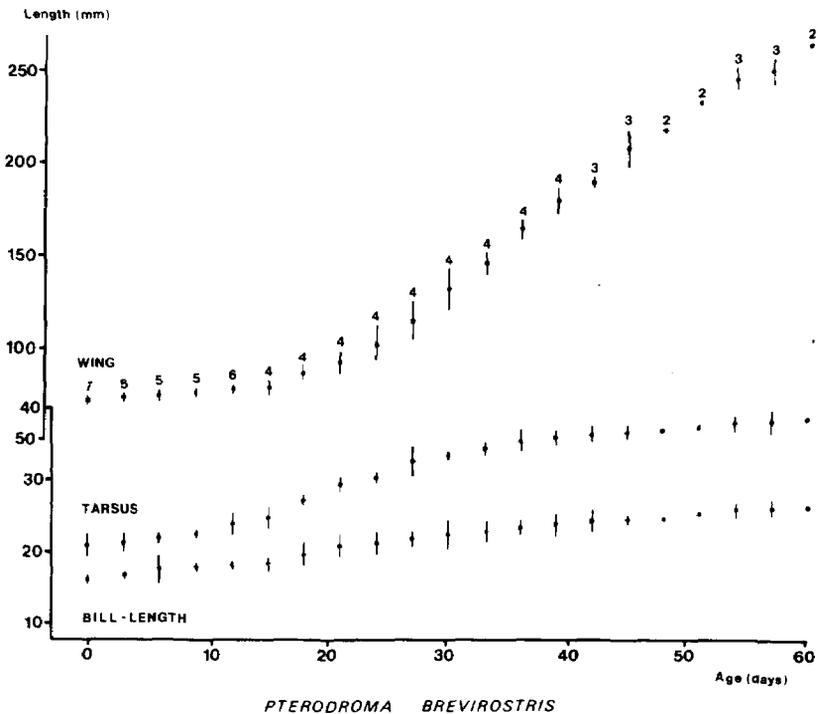


FIGURE 7 — Growth of wing, tarsus and bill length in *Pterodroma brevirostris* chicks. Mean \pm standard deviation and sample size

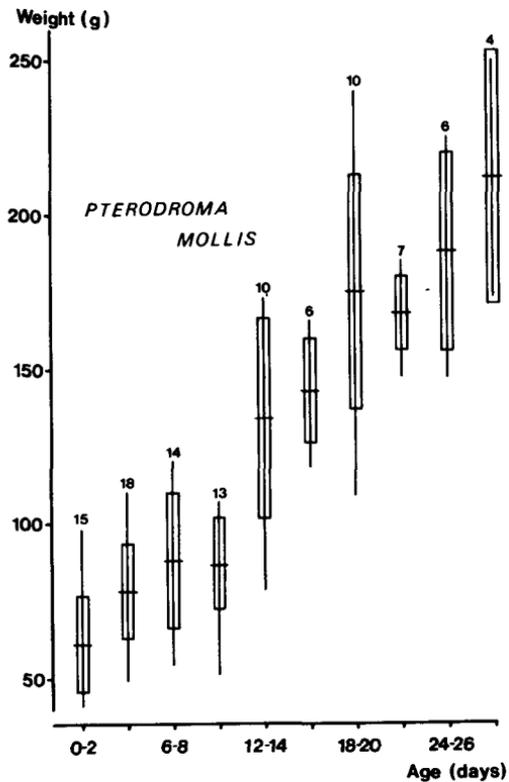


FIGURE 8 — Weight increase in *Pterodroma mollis* chicks. Mean \pm standard deviation, range and sample size

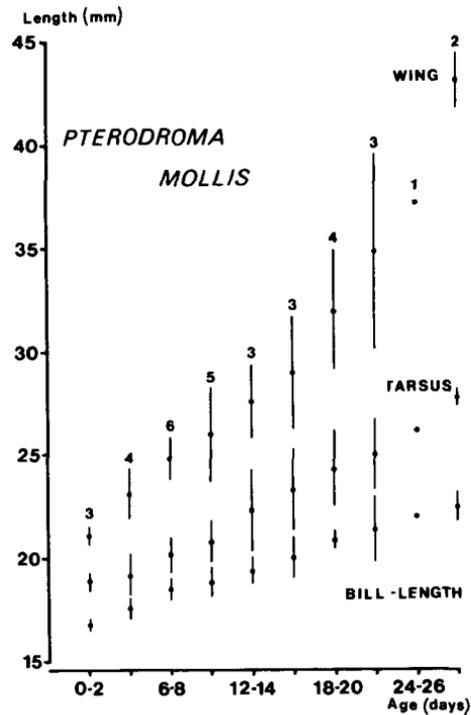


FIGURE 9 — Growth of wing, tarsus and bill length in *Pterodroma mollis* chicks. Mean \pm standard deviation and sample size

The feeding of chicks was studied for the Soft-plumaged Petrel during the weight-gain period, during the weight-decrease period for the Great-winged Petrel and for the whole growth of the Kerguelen Petrel. Similar work was not done on the White-headed Petrel. These results are given in Table 7. The Soft-plumaged Petrel received its first feed sooner than the Kerguelen Petrel and was fed more often during its period of weight gain, although it was fed only half the amount of that given to the Kerguelen Petrel. This explains the Soft-plumaged Petrel's lower rate of growth.

During the period of weight decrease, the Great-winged Petrel chicks were fed more often than Kerguelen Petrel chicks. After each feed the chicks gained approximately 10% of their previous weight, rather less than Kerguelen Petrel chicks, which gained about 22%.

If we compare the results obtained for the Kerguelen Petrel during these two periods, we see that the weight loss towards the end of rearing is caused by a decrease in feeding frequency, rather than a decrease in the feed size (27-22% of the chick weight). Here again, differences exist from year to year. During the period of weight decrease in 1970-1971 (Despin *et al.* 1972) chicks were fed every 3.6 nights, rather more often than 11 years later. However, the reduction of feeds at the end of growth was similar.

During the chick's period of weight gain, the average time each adult spent at sea was 4.4 days for the Soft-plumaged Petrel and 5.1 days for the Kerguelen Petrel. During the weight decrease phase, the adult Kerguelen Petrels spent up to 10.2 days at sea, but the adult Great-winged Petrels spent up to 5.5 days away.

Fledging

The fledging dates of the chicks are given in Table 2. The Great-winged Petrel chicks fledged over a longer period (57 days) than did the Kerguelen Petrel chicks (21 days). Most chick departures took place at the beginning of the fledging period (75% in the first month), and so the long fledging period was due to a few late departures. Departures of the Kerguelen Petrel were later than those observed previously (Despin *et al.* 1972, Mougou 1969). The dates of our stay on East Island did not allow us to observe the fledging of the Soft-plumaged Petrel chicks, and so we do not know the fledging period.

The departures of the chicks did not end the breeding cycle for the Kerguelen Petrel. Birds continued to visit the colony after fledging for the whole of February at least, and perhaps even later (Despin *et al.* 1972). The first visit to land during the non-breeding season occurred in March or April, and so the birds were not absent from their breeding colonies for long.

THE PETREL AND PRIONS

Five species of prion breed on the Crozet Islands: the Blue Petrel (*Halobaena caerulea*), the Salvin's Prion (*Pachyptila salvini*), the Antarctic Prion (*P. desolata*), the Thin-billed Prion (*P. belcheri*) and the Fairy Prion (*P. turtur*). The measurements are given in Table 8 (partly from Despin *et al.* 1972 and Derenne & Mougou 1976) and the timing of the different phases of the breeding cycle in Table 9 (partly from Paulian 1953, Tickell 1962, Richdale 1965, Despin *et al.* 1972, Derenne & Mougou 1976, and Strange 1980).

The Blue Petrel and the prions of the Crozet Islands are summer breeders but their breeding cycles are timed differently. Three of them, Salvin's Prion, the Thin-billed Prion and the Fairy Prion, are rather well synchronised, with laying occurring at the end of November and the beginning of December. The Antarctic Prion lays a month later (end of December) and the Blue Petrel a month earlier (end of October).

For all the above species the breeding season is short, lasting a maximum of five or six months between the first returns to land for courtship and the last fledging of the chicks. During winter, the Blue Petrel often returns to land in the Kerguelen Islands (Paulian 1953) and probably on Crozet also. The Fairy Prion continues to visit its colonies for some time after fledging (Derenne & Mougin 1976), whereas the Salvin's Prion does not. Winter data for the Antarctic Prion and the Thin-billed Prion are lacking. Between the first returns to land and the first laying, pairing is comparatively short for the prions on the Crozet Islands, lasting about 50-75 days according to the species (Table 9).

TABLE 7 — Chick-feeding pattern in three *Pterodroma* species

		<i>P. macroptera</i>	<i>P. brevirostris</i>	<i>P. mollis</i>
<u>Period of increase in weight</u>				
Number of chicks weighed		-	4	6
Number of weighings		-	141	90
Number of nights with visits (percent of total number of nights studied)	Mean ± S.D. Range	-	35.6 ± 4.1 30.6-40.6	40.4 ± 7.0 31.6-50.0
Interval between meals (days)	Mean ± S.D. Range	-	2.56 ± 0.34 2.18-3.00	2.26 ± 0.46 1.71-2.89
Weight increase per 24 hours when the chick is fed (g)	Mean ± S.D. Range (n)	-	59.7 ± 38.1 1-168 (150)	33.7 ± 19.5 2-73 (38)
<u>Period of decrease in weight</u>				
Number of chicks weighed		25	3	-
Number of weighings		222	52	-
Number of nights with visits (percent of total number of nights studied)	Mean ± S.D. Range	33.2 ± 12.3 11.1-55.6	18.7 ± 3.5 16.7-22.7	-
Interval between meals (days)	Mean ± S.D. Range	3.25 ± 1.61 1.50-8.74	5.20 ± 0.93 4.13-5.74	-
Weight increase per 24 hours when the chick is fed (g)	Mean ± S.D. Range (n)	56.7 ± 44.1 0-200 (72)	70.3 ± 36.2 34-134 (8)	-
<u>Total growth period</u>				
Number of chicks weighed		-	3	-
Number of weighings		-	157	-
Number of nights with visits (percent of total number of nights studied)	Mean ± S.D. Range	-	31.4 ± 2.5 29.1-34.1	-
Interval between meals (days)	Mean ± S.D. Range	-	2.93 ± 0.26 2.66-3.17	-
Weight increase per 24 hours when the chick is fed (g)	Mean ± S.D. Range (n)	-	61.9 ± 38.3 1-168 (47)	-

TABLE 8 — Weights (g) and measurements (mm) of *Halobaena caerulea* and *Pachyptila* species

Species	<i>H. caerulea</i>		<i>P. salvini</i>		<i>P. desolata</i>	<i>P. belcheri</i>	<i>P. turtur</i>	
Locality	East I	East I	Hog I	East I	East I	East I	Hog I	
Weight (g)								
Mean \pm S.D.	212 \pm 22	170 \pm 11	159 \pm 13	138	129 \pm 9	139 \pm 17	132 \pm 6	
Range (n)	171-253 (27)	140-200 (63)	130-210 (85)	116-160 (2)	115-135 (4)	118-169 (21)	122-148 (18)	
Wing length (mm)								
Mean \pm S.D.	216 \pm 4	195 \pm 5	192 \pm 5	185 \pm 4	183 \pm 4	178 \pm 4	180 \pm 4	
Range (n)	208-224 (30)	185-205 (63)	184-207 (89)	182-190 (3)	177-185 (4)	168-186 (23)	170-185 (18)	
Culmen length (mm)								
Mean \pm S.D.	26.9 \pm 0.7	30.2 \pm 3.7	30.2 \pm 1.0	27.7 \pm 1.5	25.3 \pm 1.1	22.1 \pm 1.1	22.1 \pm 1.1	
Range (n)	25.5-28.5 (30)	28.0-35.3 (64)	27.5-32.2 (89)	26.0-29.0 (3)	24.5-27.0 (4)	20.0-24.0 (24)	21.0-25.0 (18)	
Culmen breadth (mm)								
Mean \pm S.D.	-	17.2 \pm 0.7	16.9 \pm 0.8	13.9 \pm 1.3	10.8 \pm 0.7	11.1 \pm 0.7	11.4 \pm 0.9	
Range (n)	-	15.5-18.6 (63)	15.2-18.5 (89)	12.5-15.0 (3)	10.2-11.8 (4)	10.2-12.8 (15)	10.5-12.2 (18)	
Tarsus length (mm)								
Mean \pm S.D.	34.3 \pm 1.5	34.0 \pm 1.2	33.8 \pm 1.1	34.2 \pm 0.8	34.9 \pm 1.4	32.5 \pm 1.3	32.7 \pm 1.4	
Range (n)	31.2-38.2 (30)	31.2-37.5 (63)	31.0-36.8 (89)	33.5-35.0 (3)	34.0-37.0 (4)	30.0-35.0 (24)	30.2-36.0 (18)	

Reoccupation of burrows and pairing

Reoccupation of burrows by Salvin's Prion was studied by daily observations. The nest-visiting rates during this period reached a maximum in the last 10 days in October and the first 10 days in November (Fig. 10). This was followed by a minimum, corresponding with a prelaying exodus in the second 10 days of November. During pairing, Salvin's Prion was periodically present in large numbers on land. These periods of high abundance and activity in the colonies were brief (a few days to a week long) and were separated by intervals of 7.4 ± 2.4 days (range 5.4-12.0 days). Figure 11 shows the same data plotted against the laying date. The number of Salvin's Prion present on land reached a maximum shortly after reoccupation of the burrows. The numbers then rapidly decreased, reaching the first minimum on the 50th day before laying. The numbers reached a second maximum on the 30th day before laying, followed by a rapid decrease corresponding to the prelaying exodus in the last 15 days of pairing.

We lack further information on the Crozets owing to the late discovery of the Blue Petrel burrows and the difficulty of gaining access to prion colonies.

Of 367 visits noted during the pairing of Salvin's Prion, 85.3% lasted a day, 12.3% lasted two days, 2.2% lasted three days, and 0.2% lasted four days (an average of 1.2 ± 0.5 days). There were many paired birds that did not lay. Of the daily monitored burrows, 58 were visited by 202 birds, of which only 43 pairs eventually laid eggs (a non-breeding percentage of 57.4%). Of these 202 birds, 182 (90.1%) visited only one burrow, 18 (8.9%) visited two burrows and 2 (1.0%) visited three burrows. Each of the 58 observed burrows was visited by an average of 3.86 ± 2.01 Salvin's Prions (range 1-10), although burrows in which eggs were eventually laid attracted 4.32 ± 2.01 birds per burrow (range 2-10) and those that remained empty attracted 3.00 ± 1.75 birds per burrow (range 1-7), the two values being significantly different ($p < 0.01$).

Of 149 paired birds, 132 (88.6%) were faithful to only one partner during courtship, 15 (10.1%) courted two successively and 2 (1.3%) courted three. For 53 Salvin's Prion's nests, 96% of the females returned to land on the night of laying, 2% returned the night before, and 2% returned two nights before laying. Corresponding figures for the Blue Petrel were 20%, 60% and 20% for 23 nests.

Laying

Table 9 shows the chronology of laying for the Blue Petrel and prion species on the Crozet Islands. The laying period is short (10 days) for the Blue Petrel and longer (3 weeks) for Salvin's Prion. Sample numbers of the other species were too low to be useful but data on these species from other localities show laying periods of similar length (Tickell 1962, Harper 1976, Strange 1980).

Egg measurements of three of the species from Crozet are given in Table 10 (partly from Despin *et al.* 1972). The ratio of egg weight to adult weight was 17.6% for the Blue Petrel and 21.2% for Salvin's Prion.

TABLE 9 — Timing and duration of events during the breeding cycle of the prions. Values in brackets indicate estimates from data available in other localities.

	<u>H.caerulea</u>	<u>P.salvini</u>	<u>P.desolata</u>	<u>P.belcheri</u>	<u>P.turtur</u>
First returns on land	early sep	before third decade sep	late oct	early sep	late sep
Length of pre-laying period (days)	(50)	>69	(60)	(75)	
Egg-laying Mean \pm S.D. Range (n)	27 oct. 81 \pm 2 23-31 oct (23)	29 nov 81 \pm 5 18 nov -10 dec (62)	late dec	(20 nov -5 dec)	10-15 nov
Period from laying to hatching (days) Mean \pm S.D. Range (n)		49.6 \pm 3.4 46-55(6)			(56)
Real incubation period (days) Mean \pm S.D. Range (n)		44.8 \pm 1.7 42-47(6)			
Chick hatching Mean \pm S.D. Range (n)	18 dec 81 \pm 1 16-20 dec (8)	23 jan 74 \pm 6 15 jan 82 \pm 5 4-18 jan 71 14 jan -10 feb 74 (52) 7-25 jan 82 (15)	early feb	5 jan -18 jan	mid jan
Fledging period (days) Mean \pm S.D. Range (n)		59.7 \pm 2.7 54-65(34)			
Departure of fledglings from the colony Mean \pm S.D. Range (n)		23 mar 74 \pm 6 13 mar -4 apr (39)	(late mar)	23 feb.-10 mar	early mar

Number of occupied nests (%)

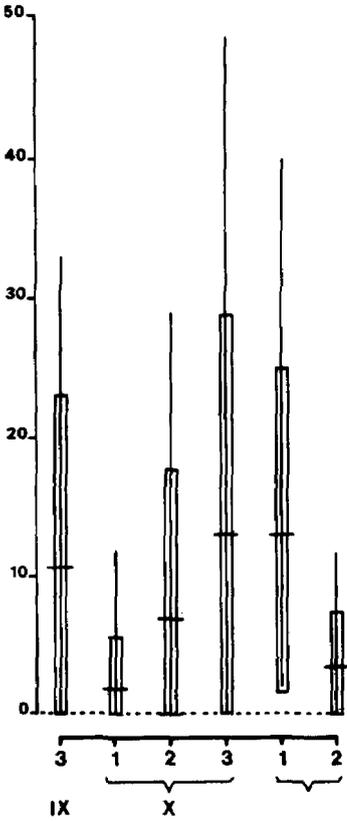


FIGURE 10 — Nest attendance by *Pachyptila salvini* from September to November

Number of occupied nests (%)

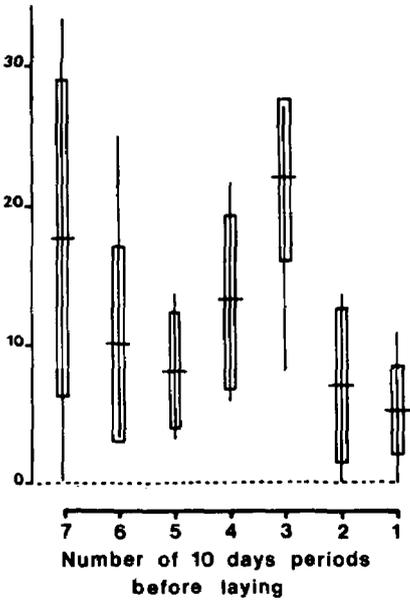


FIGURE 11 — Nest attendance by *Pachyptila salvini* before laying

We have already mentioned the very high proportion of non-breeding birds (almost 60%) observed for Salvin's Prion. The proportion of visited burrows that had no egg laid was also high, 20 out of 58 (34.5%), but 62 eggs were laid in 53 observed burrows. In 47 of these nests (88.7%) one laying occurred, in 3 (5.7%) of them two pairs laid in succession, and in the other 3 nests (5.7%) three pairs laid.

Incubation

Incubation shifts were studied for the Blue Petrel and Salvin's Prion. The results given in Table 11 show a rather distinct difference between the two species. In both species, the female's first shift is shorter and the male's longer than those that follow. Although incubation periods are of similar length (46 days for *Halobaena caerulea* and 45 days for *Pachyptila salvini*), the shifts of the Blue Petrel are fewer and longer than those of Salvin's Prion (Table 12). Work distribution between the sexes is similar for both species.

TABLE 10 — Weights (g) and dimensions (mm) of eggs of *Halobaena caerulea* and *Pachyptila* species

	<i>H. caerulea</i>	<i>P. salvini</i>	<i>P. belcheri</i>
Weight			
Mean \pm S.D.	38.3 \pm 2.6	36.1 \pm 1.1	
Range (n)	33-43(20)	34-38(15)	
Length			
Mean \pm S.D.	51.1 \pm 1.4	49.2 \pm 1.5	48.6
Range (n)	48.5-54.5(21)	45.7-52.4(65)	46.0-51.1(2)
Breadth			
Mean \pm S.D.	37.7 \pm 1.0	35.7 \pm 1.1	34.6
Range (n)	35.5-39.1(21)	33.5-38.7(65)	33.0-36.2(2)

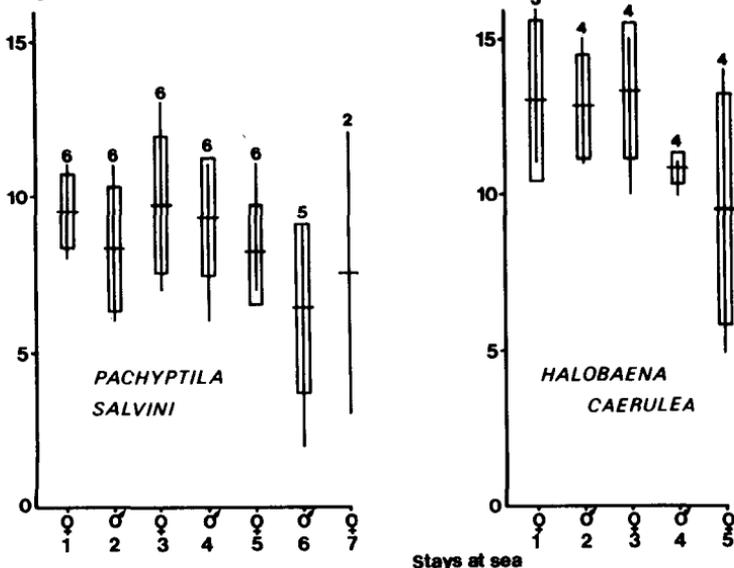
TABLE 11 — Incubation shifts and egg desertions in *Halobaena caerulea* and *Pachyptila salvini*

	Length of stay in burrow (days)		Length of desertion (days)		Desertion frequency (per cent)	
	<i>H. caerulea</i>	<i>P. salvini</i>	<i>H. caerulea</i>	<i>P. salvini</i>	<i>H. caerulea</i>	<i>P. salvini</i>
First shift (♀)						
Mean \pm S.D.	1.5 \pm 0.6	2.9 \pm 2.5	0	0	0	0
Range (n)	1-2(4)	0.5-7 (6)	(4)	(6)	(4)	(6)
Second shift (♂)						
Mean \pm S.D.	12.7 \pm 2.9	9.0 \pm 1.5	0.3 \pm 0.6	0.5 \pm 1.2	33	17
Range (n)	11-16 (3)	7-11 (6)	0-1(3)	0-3(6)	(3)	(6)
Third shift (♀)						
Mean \pm S.D.	8.9 \pm 1.4	7.2 \pm 1.0	4.3 \pm 2.2	0.7 \pm 0.8	88	33
Range (n)	7-11 (8)	6-9(6)	0-7(8)	0-3(6)	(8)	(6)
Fourth shift (♂)						
Mean \pm S.D.	8.0 \pm 2.3	7.5 \pm 1.4	2.3 \pm 2.3	1.5 \pm 0.5	75	100
Range (n)	4-10 (8)	6-9(6)	0-6(8)	1-2(6)	(8)	(6)
Fifth shift (♀)						
Mean \pm S.D.	7.6 \pm 1.7	6.8 \pm 1.0	0.9 \pm 1.9	1.0 \pm 1.1	29	50
Range (n)	6-10 (7)	5-8(5)	0-5(7)	0-2(6)	(7)	(6)
Sixth shift (♂)						
Mean \pm S.D.	8.0 \pm 2.2	7.0 \pm 1.3	0	0.2 \pm 0.4	0	17
Range (n)	5-10 (4)	6-9(6)	(4)	0-1(6)	(4)	(6)
Seventh shift (♀)						
Mean \pm S.D.	-	5.0 \pm 2.5	-	1.2 \pm 2.2	-	40
Range (n)	-	2-8(5)	-	0-5(5)	-	(5)
Eighth shift (♂)						
Mean	-	5.0	-	0	-	0
Range (n)	-	3-7 (2)	-	(2)	-	(2)

TABLE 12 — Incubation schedule in *Halobaena caerulea* and *Pachyptila salvini*

	<i>H.caerulea</i>	<i>P.salvini</i>
INCUBATION		
Mean length of a shift (days)		
both sexes		
Mean \pm S.D.	7.8 \pm 3.2	6.5 \pm 2.4
Range (n)	1-16(34)	0.5-11(43)
male		
Mean \pm S.D.	8.9 \pm 2.9	7.6 \pm 2.8
Range (n)	4-16(15)	3-11(20)
female		
Mean \pm S.D.	6.8 \pm 3.2	5.5 \pm 2.5
Range (n)	1-11(19)	0.5-9(23)
DESERTION		
Mean number of periods per nest		
Mean \pm S.D.	2.0 \pm 0.8	2.5 \pm 1.0
Range (n)	1-3(4)	1-4(6)
Total length per nest (days)		
Mean \pm S.D.	5.6 \pm 1.7	4.8 \pm 2.5
Range (n)	4-8(4)	1-8(6)
Mean length of a period (days)		
Mean \pm S.D.	2.9 \pm 1.9	1.9 \pm 1.1
Range (n)	1-5(8)	1-5(15)
Frequency of nest-reliefs with desertion (per cent)		
Mean \pm S.D.	43.3 \pm 11.5	41.2 \pm 17.4
Range (n)	33.3-60.0(4)	14.3-66.7(6)
STAYS AT SEA		
Mean length (days)		
both sexes		
Mean \pm S.D.	10.0 \pm 4.6	7.8 \pm 3.0
Range (n)	1-16(23)	0.5-13(43)
male		
Mean \pm S.D.	8.3 \pm 5.2	6.8 \pm 3.3
Range (n)	1-15(12)	0.5-11(23)
female		
Mean \pm S.D.	11.8 \pm 3.2	9.0 \pm 2.2
Range (n)	5-16(11)	3-13(20)

Length of the stay at sea (days)

FIGURE 12 — Duration of sojourns at sea in *Pachyptila salvini* and *Halobaena caerulea* throughout incubation. Mean \pm standard deviation, range and sample size

We obtained only a small amount of similar information about the other prions on the Crozet Islands. For the Fairy Prion, one male's first incubation shift lasted at least eight days and another at least five days, with a desertion of two days before the female returned.

The eggs were deserted fairly frequently during incubation, two or three times for a total of five or six days in both the Blue Petrel and Salvin's Prion (Tables 11 and 12). The longest and most frequent desertions occurred in the middle of incubation, that is, after the third shift for *Halobaena caerulea* and after the fourth for *Pachyptila salvini*.

Sojourns at sea for both sexes were relatively long in the two species studied. However, they were more numerous and shorter ($t=2.35$; $p < 0.05$) for Salvin's Prion than for the Blue Petrel, and in both species, longer for females than for males (Fig. 12). The dates of hatching for the Crozet prions and Blue Petrel are given in Table 9. As in the laying dates, the hatching dates were similar for Salvin's Prion, the Thin-billed Prion and the Fairy Prion, later for the Antarctic Prion and earlier for the Blue Petrel. Hatching was highly synchronised for the Blue Petrel, where all hatching occurred over five days. For Salvin's Prion, at least, small differences exist from year to year; the similar values obtained in 1971 and 1982 are significantly earlier than those of 1974 (Derenne & Mougin 1976).

The total and actual incubation lengths are given in Table 9. A characteristic of this group is that all the species studied so far have an actual incubation length averaging 45-47 days.

The thermic emancipation of prion chicks on Crozet was early, usually a few hours after hatching.

Chick growth

Weight gain data for Blue Petrel and Salvin's Prion chicks are given in Tables 13 and 14 and Figures 13 and 14. Chick growth was rapid at first, slowing down until the chick reached a maximum weight of about 15% more than the adult. By this time the chick was about three-quarters fully fledged. The rate of weight gain in 3-day periods was $19.3 \pm 24.0\%$ in the Blue Petrel and $13.8 \pm 19.6\%$ in Salvin's Prion, which had a longer rearing period. Thereafter chicks lost approximately 15% of their maximum weight at a rate of $0.6 \pm 4.8\%$ for the Blue Petrel and $0.9 \pm 3.4\%$ for Salvin's Prion. For both species fledging weight was slightly less than the adult weight.

As shown in Fig. 15 and the growth curves published elsewhere (Derenne & Mougin 1976), the wing growth was slow before the appearance of the primaries, becoming more rapid with the appearance of these feathers, then slowing down as fledging approached. The average rate of wing growth in 3-day periods was $17.2 \pm 12.4\%$ for the Blue Petrel and $12.4 \pm 8.7\%$ for Salvin's Prion. At fledging, the wings of the chicks of both species measured approximately 90% of those of the adults.

As usual the rather rapid growth of the culmen and tarsus in young chicks slowed down as fledging approached, almost stopping in the Salvin's Prion. At fledging, full development was reached in both species. We do not have similar data for the other prions of Crozet.

TABLE 13 — Weight growth in *Halobaena caerulea* and *Pachyptila salvini* chicks

	<i>H.caerulea</i>	<i>P.salvini</i>
Weight at birth		
Weight (g.)		
Mean \pm S.D.	37.5	26.0 \pm 3.7
Range (n)	37-38(2)	21-32(8)
Percent adult weight	18	16
Maximum weight		
Weight (g.)		
Mean \pm S.D.	240	186 \pm 29
Range (n)	220-260(2)	140-270(17)
Percent adult weight	113	117
Age at peak weight (days)		
Mean \pm S.D.	33	44 \pm 11
Range (n)	31-34(2)	25-61(17)
Weight at fledging		
Weight (g.)		
Mean \pm S.D.	208	154 \pm 22
Range (n)	200-215(2)	115-200(17)
Percent adult weight	98	97

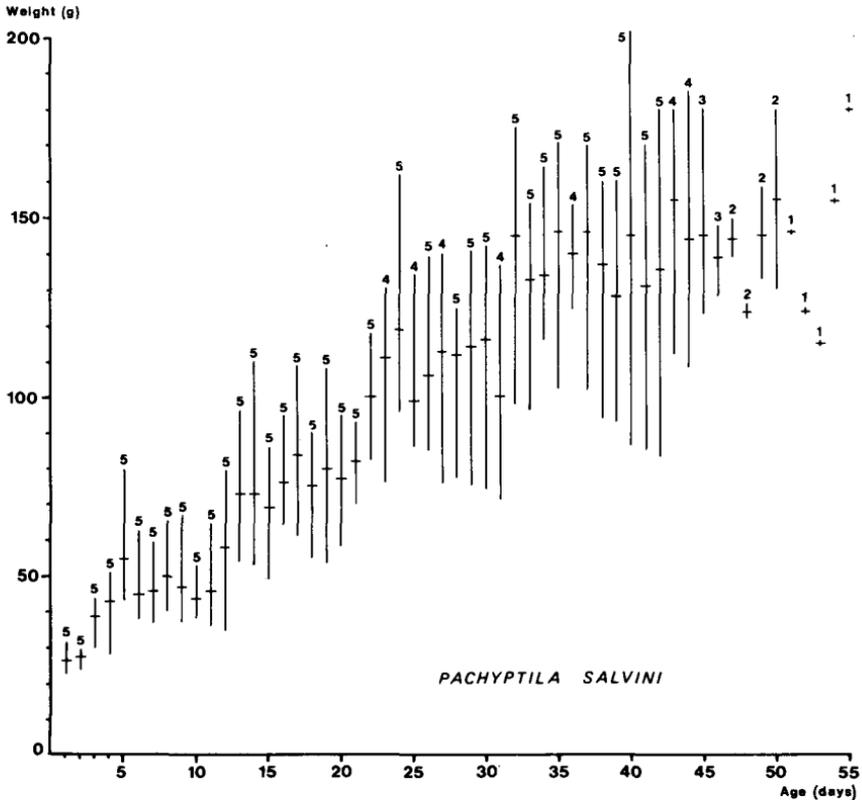


FIGURE 13 — Weight increase in *Pachyptila salvini* chicks. Mean, range and sample size

TABLE 15 — Chick-feeding pattern in *Halobaena caerulea* and *Pachyptila salvini*

Period of increase in weight		<i>H. caerulea</i>	<i>P. salvini</i>
Number of chicks weighed		9	7
Number of weighings		68	272
Number of nights with visits (percent of total number of nights studied)	Mean \pm S.D.	54.4 \pm 7.5	54.4 \pm 9.7
	Range	40.0-66.7	41.5-71.8
Interval between meals (days)	Mean \pm S.D.	1.57 \pm 0.29	1.59 \pm 0.34
	Range	1.18-2.22	1.07-2.13
Weight increase per 24 hours when the chick is fed (g)	Mean \pm S.D.	30.6 \pm 24.9	18.1 \pm 14.2
	Range (n)	0-127 (38)	0-53 (119)
Period of decrease in weight			
Number of chicks weighed		5	6
Number of weighings		33	37
Number of nights with visits (percent of total number of nights studied)	Mean \pm S.D.	23.1 \pm 10.0	38.6 \pm 10.0
	Range	12.5-33.3	25.0-50.0
Interval between meals (days)	Mean \pm S.D.	4.83 \pm 2.31	2.47 \pm 0.77
	Range	2.72-7.74	1.71-3.73
Weight increase per 24 hours when the chick is fed (g)	Mean \pm S.D.	25.6 \pm 12.8	16.4 \pm 13.2
	Range (n)	8-44 (7)	0-36 (14)
Total growth period			
Number of chicks weighed		10	10
Number of weighings		108	270
Number of nights with visits (percent of total number of nights studied)	Mean \pm S.D.	42.8 \pm 12.3	49.5 \pm 5.8
	Range	25.0-60.0	41.4-57.1
Interval between meals (days)	Mean \pm S.D.	2.29 \pm 0.90	1.75 \pm 0.25
	Range	1.36-3.73	1.45-2.13
Weight increase per 24 hours when the chick is fed (g)	Mean \pm S.D.	29.8 \pm 23.5	18.0 \pm 14.0
	Range (n)	0-127 (45)	0-53 (133)

The average length of time spent at sea by the breeding birds during the period of chick weight loss was 8.1 days in the Blue Petrel compared with 3.1 days during the earlier period of weight gain. A smaller increase from 3.1 to 4.6 days occurred with the Salvin's Prion.

Fledging

The dates of fledging are given in Table 9. The departure period was brief in all species, never exceeding 3 weeks.

The fledging period on Crozet is particularly short for the Blue Petrel (43 days) and particularly long for Salvin's Prion (60 days, Derenne & Mougouin 1976). Data for the other prions on Crozet are lacking, but in other localities where they have been studied, the fledging period for prions is usually about 50 days (Richdale 1944, 1965, Tickell 1962, Strange 1980).

GENUS PROCELLARIA

Of the four species of *Procellaria*, two nest on the Crozet Islands: the White-chinned Petrel (*P. aequinoctialis*) and the Grey Petrel (*P. cinerea*). Table 16 gives the measurements of these birds and Table 17 the timing of their breeding cycles (partly from Mougouin 1970 and 1971, Despin *et al.* 1972, Barrat 1974, Despin 1976). These relatively large petrels have a long breeding season with eight or nine months passing between the first return of adults to land for pairing and their last departure (much later than the last fledging). Neither petrel on Crozet has ever been observed ashore during the non-breeding season. The White-chinned Petrel is a summer breeder; the Grey Petrel nests in winter.

TABLE 16 — Weights (g) and measurements (mm) of *Procellaria petrels*

	<i>P. aequinoctialis</i>	<i>P. cinerea</i>
Weight (g)		
Mean \pm S.D.	1213 \pm 134	1073 \pm 137
Range (n)	980-1885 (87)	950-1220 (3)
Wing length (mm)		
Mean \pm S.D.	372 \pm 11	345 \pm 4
Range (n)	350-395 (30)	340-350 (5)
Culmen length (mm)		
Mean \pm S.D.	52.3 \pm 2.0	46.3 \pm 1.9
Range (n)	47.0-56.0 (30)	44.5-49.0 (5)
Tarsus length (mm)		
Mean \pm S.D.	65.0 \pm 2.4	64.0 \pm 3.4
Range (n)	61.0-70.0 (30)	62.0-70.0 (5)

TABLE 17 — Timing and duration of events during the breeding cycle of *Procellaria petrels*

	<i>P. aequinoctialis</i>	<i>P. cinerea</i>
First returns on land	15 sep 66 16 sep 68	early feb
Length of pre-laying period (days)		
Mean \pm S.D.	48.6 \pm 9.6	45
Range (n)	36-68(17)	
Laying period		
Mean \pm S.D.	22 nov 68 \pm 13 21 nov 81 \pm 4	second fortnight of mar
Range (n)	8 nov -20dec 68 (19) 18-25 nov 81(3)	
Length of incubation (days)		
Mean	57.5	60
Range (n)	57-58(2)	
Hatching period		
Mean \pm S.D.	12 jan 68 \pm 5 12 jan 69 \pm 1 11 jan 71 \pm 7 12 jan 82 \pm 2	second fortnight may
Range (n)	2-16 jan 68(6) 11-13 jan 69(2) 6-16 jan 71(2) 10-14 jan 82(4)	
Fledging period (days)		
Mean \pm S.D.	95.7 \pm 4.9	110
Range (n)	91-105(6)	
Departure of fledglings from the colony		
Mean \pm S.D.	17 apr 68 \pm 8	mid sep
Range (n)	4-29 apr (6)	
Last departure of adults	7 may 68	20 oct 82

Reoccupation of burrows and pairing

Compared with the length of the breeding period, pairing (from first reoccupation of a burrow until laying) is relatively short on Crozet, lasting for about 45-50 days for both species. The 60 White-chinned Petrel nests studied showed an important variation in the daily rate of occupation (Fig. 16). For the first 30 days of courtship (from mid-September to mid-October) the rate was constant, declining as a result of the prelaying exodus of both sexes to become rather low at the end of October and the beginning of November. Figure 17 shows the mean rate of occupation of the 13 nests in which eggs were laid, plotted against the mean laying date of those 13 nests, recalculated from Mougín 1970. The rate of visiting was nearly constant between the 50th and the 21st day before laying, but in the last 20 days before laying, the prelaying exodus depopulated the colonies and only 5% of the nests were visited daily. Of the 174 observed periods of time spent on land, 76.4% did not last longer than a day, 17.2% lasted two days, 5.2% lasted three days, 0.6% lasted five days and 0.6% lasted six days (an average of 1.3 ± 0.7 days).

Many non-breeding White-chinned Petrels were on land during courtship (Mougín 1970). Thirty-one nests were visited by 69 birds, of which only 19 pairs eventually nested (44.9% non-breeders). Of these 69 birds, 50 (72.5%) visited only one burrow, 13 (18.8%) visited two, 5 (7.2%) visited three, and 1 (1.5%) visited six. Each of the 31 nests was visited by an average of 3.19 ± 1.96 birds (range 1-10), but there appeared to be no significant difference

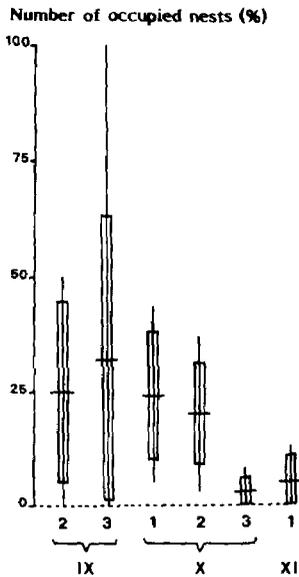


FIGURE 16 — Nest attendance by *Procellaria aequinoctialis* from September to November

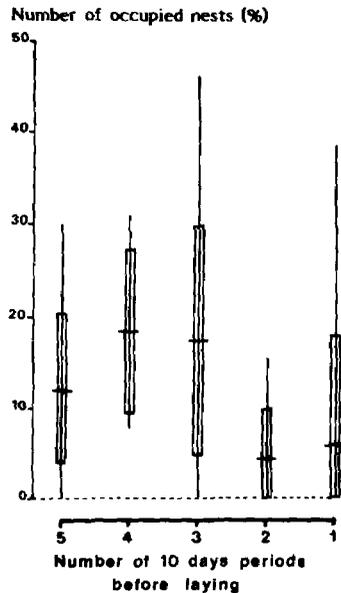


FIGURE 17 — Nest attendance by *Procellaria aequinoctialis* from September to November

between burrows in which eggs were laid (3.06 ± 2.01 birds, range 2-10) and those that remained empty (3.29 ± 1.94 birds, range 1-7).

The high mobility of adults during pairing did not stop after laying. Of the 32 nests monitored daily during chick rearing, Mougín (1970) observed on average 2.00 ± 0.95 birds visiting each nest (range 1-4) and 1.23 ± 0.58 nests frequented by each bird (range 1-4).

During pairing, 35 birds were observed accompanied by a partner. Of these, 33 birds were faithful to only one partner, 1 had two partners, and 1 had three. No similar work was done for the Grey Petrel.

Laying

The White-chinned Petrel females returned just before laying, that is, at the end of the prelaying exodus. Laying took place on the night of return in 64% and on the next night in 36% (14 nests, Mougín 1970). Eggs of the White-chinned Petrel are laid at the end of the spring and those of the Grey Petrel at the beginning of autumn, the dates being fairly consistent from year to year (Table 17). Laying can be well spread. A month and a half has been recorded for the White-chinned Petrel, but almost three-quarters of the eggs were laid in the first 15 days and a few late breeders extended this time by another month (Mougín 1970).

Egg measurements are given in Table 18 (partly from Mougín 1970, Despin *et al.* 1972 and Barrat 1974). The ratio of egg weight to adult weight is 10.4% for the White-chinned Petrel and about 10.3% for the Grey Petrel (Barrat 1974).

As well as the high proportion of non-breeders already mentioned for *Procellaria aequinoctialis*, in a high proportion of nests no eggs were laid (13 out of 31 nests studied, or 42%). Nineteen eggs were laid in the 18 other nests, a second pair laying in one nest where a first pair had lost its egg.

Incubation

The incubation shifts of the White-chinned Petrel are shown in Fig. 18 (data from Mougín 1970 and 1971). As usual, females spent only a short time on the nest after laying. The following shifts were longer, but shortened after the fifth. The shifts of the males lasted for an average of 9.5 ± 2.2 days (range 5-13 days for 13 shifts) and those of the females 6.1 ± 4.3 days (range 1-15 for 18 shifts). For 4 nests the number of shifts was 6 or 7. In total, the female's share of the incubation was 45% and the male's 55%. No temporary egg desertions were observed for any successful breeders. Temporary desertions resulted eventually in total desertion (Mougín 1970). During incubation, the time spent at sea was equal to the time spent on land, the total incubation period lasting for an average of 57.5 days (Mougín 1971).

We do not have similar data on the Grey Petrel for the Crozets or any other breeding locality, although the incubation period for the Grey Petrel on Crozet was about 2 months, similar to that of the White-chinned Petrel.

Grey Petrel chicks hatched at the end of autumn and the White-chinned Petrel chicks in the middle of summer (Table 17). We have pointed out the short hatching period for the White-chinned Petrel (15 days from first to last hatching), which contrasts with the long laying period. Late layings were rare and were usually abandoned during incubation, reducing the length of the

hatching period. The synchrony of hatching from year to year is remarkable with a mean hatching date of 12 January in 1968, 1969 and 1982 and 11 January in 1971.

The chicks of both the White-chinned Petrel (Mougin 1970) and the Grey Petrel became thermically emancipated very quickly, brooding ceasing a few hours after hatching, but the chicks continued to be accompanied by a parent for the next 24-72 hours.

TABLE 18 — Weights (g) and dimensions (mm) of *Procellaria* petrel eggs

	<i>P. aequinoctialis</i>	<i>P. cinerea</i>
Weight (g)		
Mean ± S.D.	126 ± 8	-
Range (n)	115-140 (8)	
Length (mm)		
Mean ± S.D.	82.2 ± 3.4	79.2
Range (n)	77.3-90.0 (17)	78.4-80.0 (2)
Breadth (mm)		
Mean ± S.D.	53.8 ± 1.4	56.2
Range (n)	51.3-56.6 (17)	55.2-57.2 (2)

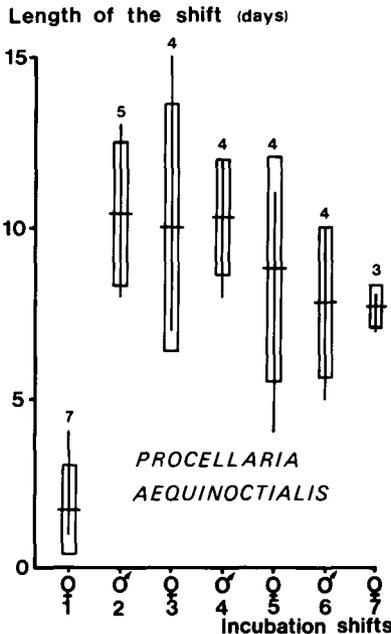


FIGURE 18 — Length of incubation shifts in *Procellaria aequinoctialis*. Mean ± standard deviation, range and sample size

Chick growth

Weight increase is given in Table 19 (partly from Mougin 1970, Barrat 1974, Despin 1976). The rate of increase in weight in 3-day periods for the White-chinned Petrel reached 15.3%. The chicks reached a maximum weight of 17% more than the adult weight after two-thirds of the fledging period. The chicks then lost 30% of their maximum weight at a rate of weight decrease in 3-day periods of 1.9%.

The Grey Petrel chicks' rate of increase in weight of 6.9% in 3-day periods was much less than that of the White-chinned Petrel. The chicks reached a maximum weight of 37% more than the adult weight by the time that they were three-quarters fledged. The weight loss that followed was much less than that of the White-chinned Petrel, 14% of their maximum weight being lost at a rate of 2.3% in 3-day periods.

The rate of wing growth in 3-day periods was remarkably low for the White-chinned Petrel (8.6%), but even lower for the Grey Petrel (7.1%). Adult length was usually not reached by the time the chicks fledged. The culmen and tarsus grew slowly in both species but almost reached adult measurements by fledging.

While chick feeding of the White-chinned Petrel was studied only during the weight-gain period, the whole of rearing for the Grey Petrel (Table 20) was observed for a single bird and the weight-decrease period for another one. During the weight-gain period, the White-chinned Petrel chicks were fed less often than those of the Grey Petrel, but the meals were larger. This could explain the more rapid growth of the White-chinned Petrel chicks. During the weight-decrease period, the Grey Petrel chicks were fed less often but the size of the meals remained the same. This slow reduction of feeding probably explains the smaller weight loss during the weight-decrease period, at least for the chicks studied.

During the chicks' weight-increase period, the adult White-chinned Petrels spent an average of 3.8 days at sea, compared with 3.2 days for the Grey Petrel. During the chicks' weight-decrease period the Grey Petrel spent an average of 3.8 days at sea.

Fledging

The Grey Petrel chicks fledged at the beginning of spring and the White-chinned Petrel chicks in the middle of autumn, both fledging periods lasting about 3 weeks (Table 17). The time from hatching to fledging differed for the two species, about 96 days for the White-chinned Petrel and 110-120 days for the Grey Petrel (slightly shorter than for the only other winter breeder on Crozet, the Great-winged Petrel - *Pterodroma macroptera*).

STORM PETRELS

Three species of storm petrels breed on the Crozet archipelago, the Wilson's Storm Petrel (*Oceanites oceanicus*), the Grey-backed Storm Petrel (*Garrodia nereis*) and the Black-bellied Storm Petrel (*Fregatta tropica*). Table 21 shows the measurements of these birds (partly from Prévost 1970, Despin *et al.* 1972) and Table 22 the timing of their breeding cycles (partly from Beck & Brown 1971 and 1972, Despin *et al.* 1972, Lacan 1972, Turner 1980).

TABLE 19 — Weight growth in *Procellaria petrei* chicks

	<i>P.aequinoctialis</i>	<i>P.cinerea</i>
Weight at birth		
Weight (g.)	94(1)	
Maximum weight		
Weight (g.)		
Mean \pm S.D.	1417 \pm 203	1447 \pm 216
Range (n)	1200-1740(6)	1200-1600(3)
Percent adult weight	117	137
Age at peak weight (days)		
Mean \pm S.D.	58.8 \pm 8.4	84.5
Range (n)	48-70(6)	75-94(2)
Weight at fledging		
Weight (g.)		
Mean \pm S.D.	1000 \pm 200	1207 \pm 136
Range (n)	680-1230(6)	1050-1290(3)
Percent adult weight	82	112

TABLE 20 — Chick-feeding pattern in *Procellaria petrei*

	<i>P.aequinoctialis</i>	<i>P.cinerea</i>
<u>Period of increase in weight</u>		
Number of chicks weighed	6	1
Number of weighings	156	94
Number of nights with visits (percent of total number of nights studied)	Mean \pm S.D. Range	53.2
	45.4 \pm 7.8 35.7-55.6	
Interval between meals (days)	Mean \pm S.D. Range	1.58
	1.97 \pm 0.42 1.50-2.52	
Weight increase per 24 hours when the chick is fed (g)	Mean \pm S.D. Range (n)	112.0 \pm 93.7 0-420(50)
	133.1 \pm 102.6 0-530(72)	
<u>Period of decrease in weight</u>		
Number of chicks weighed		2
Number of weighings		30
Number of nights with visits (percent of total number of nights studied)	Mean Range	45.8 41.7-50.0
Interval between meals (days)	Mean Range	1.92 1.71-2.12
Weight increase per 24 hours when the chick is fed (g)	Mean \pm S.D. Range (n)	113.1 \pm 160.7 10-590(13)
<u>Total growth period</u>		
Number of chicks weighed		1
Number of weighings		118
Number of nights with visits (percent of total number of nights studied)		50.8
Interval between meals (days)		1.67
Weight increase per 24 hours when the chick is fed (g)	Mean \pm S.D. Range (n)	112.3 \pm 109.3 0-590(63)

TABLE 21 — Weights (g) and measurements (mm) of storm petrels

	<i>O. oceanicus</i>	<i>G. nereis</i>	<i>F. tropica</i>
Weight (g)			
Mean \pm S.D.	32 \pm 3	32 \pm 5	52 \pm 3
Range (n)	27-39 (31)	25-42 (16)	43-59 (38)
Wing length (mm)			
Mean \pm S.D.	143 \pm 4	127 \pm 6	163 \pm 5
Range (n)	134-154 (29)	116-134 (18)	155-175 (54)
Culmen length (mm)			
Mean \pm S.D.	12.1 \pm 0.4	13.6 \pm 0.7	15.4 \pm 0.6
Range (n)	11.4-13.0 (30)	12.5-15.0 (18)	14.2-17.0 (54)
Tarsus length (mm)			
Mean \pm S.D.	34.8 \pm 1.1	32.6 \pm 1.4	40.9 \pm 1.4
Range (n)	32.5-37.0 (30)	30.0-34.0 (18)	38.2-44.5 (54)

TABLE 22 — Timing and duration of events during the breeding cycle of the storm petrels. Values in brackets indicate estimates from data available from other localities.

	<i>O.oceanicus</i>	<i>G.nereis</i>	<i>F.tropica</i>
First return on land	16 nov 81	17 oct 81	27 sep 81
Length of pre-laying period (days)	45	60	80
Laying period			
Mean \pm S.D.	2 jan 82 \pm 10		20 dec \pm 5
Range (n)	18 dec -15 jan (20)	15-29 dec 70	15-31 dec (7)
Period from laying to hatching (days)			
Mean \pm S.D.	49.7 \pm 5.4		
Range (n)	44-59(6)		61(1)
Real incubation period (days)			
Mean \pm S.D.	35.7 \pm 1.8		
Range (n)	33-38(6)		39(1)
Hatching period			
Mean \pm S.D.	16 feb 82 \pm 10		7 feb 82 \pm 8
Range (n)	31 jan -2 mar (6)	1-13 feb 71	31 jan -16 feb (3)
Departure of fledglings from the colony	[late mar -early apr]		[mid apr]

The Black-bellied Storm Petrel is much larger than the other two species, which are about the same size. The length of the breeding reflects these size differences. The period between the first return to land of the adults and the last departure of the fledglings is 5 months in *Oceanites oceanicus*, 6 months in *Garrodia nereis* and 7 months in *Fregetta tropica*. All breed in summer. Although pairing begins at different times of the year for each species (September to November), the chicks fledge at the same time (end of March to beginning of April). The colonies of the three species are probably deserted between the breeding seasons as these birds are almost absent around the Crozet Islands in winter (Stahl, Weimerskirch, unpubl.).

Reoccupation of burrows and pairing

The courtship period varied between species, lasting about 1.5 months for Wilson's Storm Petrel, 2 months for the Grey-backed Storm Petrel and almost 3 months for the Black-bellied Storm Petrel (Table 22).

During pairing, the colonies were visited periodically by *Fregetta tropica* and *Garrodia nereis*. For *F. tropica*, the periods of abundance occurred every 15.5 ± 1.5 days, the last cycle before laying being shorter (9.8 days). For *G. nereis*, the cycles measured 16.5 ± 0.7 days. Nothing similar was observed for the Wilson's Storm Petrel, for which the number of visits made each night remained fairly constant. We noticed, however, that visiting decreased between the 43rd and the 27th day before laying, with more regular visiting (almost daily) occurring between the 26th and the 14th day before laying. A desertion then occurred, lasting until laying (the prelaying exodus). All visits were brief, none lasting more than one day.

Table 23 shows the reoccupation of burrows for Wilson's Storm Petrel and the Black-bellied Storm Petrel. For the Wilson's Storm Petrel (21 nests) and the Black-bellied Storm Petrel (4 nests), the time the females spent on the nest before laying was brief because they returned to land only on the night of laying.

Laying

Although the three Storm Petrels first returned to land in different months, their laying was well synchronised, in the second half of December in *Fregetta tropica* and *Garrodia nereis* and from the second half of December to the beginning of January in *Oceanites oceanicus*. The laying period lasted 15 days for the first two species and about 1 month for Wilson's Storm Petrel, the laying of the eggs being evenly distributed throughout this period in all three species (Table 22).

Table 24 shows the measurements of eggs from the Crozet Islands (partly from Despin *et al.* 1972). The ratio of the egg weight to the adult weight was approximately the same for the three species, 30.0% in Wilson's Storm Petrel, 28.1% in the Grey-backed Storm Petrel and 28.8% in the Black-bellied Storm Petrel.

TABLE 23 — The nest reoccupation by the storm petrels

	<i>O. oceanicus</i>	<i>F. tropica</i>
Number of birds observed	52	32
Breeders	42 (80.8 %)	6 (18.8 %)
Non breeders	10 (19.2 %)	26 (81.2 %)
Number of nests studied	25	17
Nests with egg-laying	21 (84.0 %)	3 (18.0 %)
Nests without egg-laying	4 (16.0 %)	14 (82.0 %)
Number of birds per burrow		
Mean \pm S.D	2.1 ± 0.4	1.9 ± 1.0
Range	(1-3)	(1-5)
Number of burrows visited per bird	1	1
Number of mates per bird		
Mean \pm S.D	1.1 ± 0.3	1.1 ± 0.3
Range	(1-2)	(1-2)

TABLE 24 — Weights (g) and dimensions (mm) of storm petrel eggs

	<i>O. oceanicus</i>	<i>G. nereis</i>	<i>F. tropica</i>
Weight (g)			
Mean \pm S.D.	9.6 \pm 1.6	9.0 \pm 0.7	15.0 \pm 1.2
Range (n)	8-15 (16)	8.5-10 (8)	14-17 (5)
Length (mm)			
Mean \pm S.D.	31.5 \pm 1.1	33.2 \pm 1.9	37.0 \pm 2.1
Range (n)	30.0-33.1 (16)	31.6-37.5 (8)	34.6-39.9 (5)
Breadth (mm)			
Mean \pm S.D.	22.9 \pm 0.8	24.3 \pm 1.1	26.8 \pm 0.6
Range (n)	21.2-24.3 (16)	22.7-25.7 (8)	26.1-27.5 (5)

Incubation

The incubation shifts were studied for Wilson's Storm Petrel and the Black-bellied Storm Petrel. The results, given in Table 25, show a rather large difference between the two species ($t = 8.15$, $p < 0.001$). During incubation, the shifts of both sexes are significantly shorter for *Oceanites oceanicus* than for *Fregatta tropica* although no changes in the length of the shifts were observed as incubation progressed in both species. Incubation was shared equally between the sexes. We have no detailed data for the Grey-backed Storm Petrel. Four observations of shift length varied from 1 to 3 days (average 1.5 days), a figure similar to that for the Wilson's Storm Petrel.

Poor synchronisation of the changing of shifts between the two partners meant that there were frequent desertions at the end of the incubation spells for both Wilson's Storm Petrel and the Black-bellied Storm Petrel. Up to 18 desertions were noted for a single nest for a total length of up to one month without damage to the egg. No significant difference in egg desertions was seen between the male and the female (Tables 25 and 26). The small amount of data obtained for the Grey-backed Storm Petrel concerned a single nest for which three shifts were observed, each followed by a desertion. Each desertion lasted 3.0 ± 2.0 days (range 1-5 days).

For Wilson's Storm Petrel, desertions also occurred during incubation shifts. These desertions were observed in only 9.4% of the 159 shifts studied, each lasting an average of 1.2 ± 0.4 days (range 1-2 days for 15 desertions). Desertions of this kind also occurred in the Grey-backed Storm Petrel but were not observed in the Black-bellied Storm Petrel.

Periods of time spent at sea by both sexes were relatively long, the Black-bellied Storm Petrel spending longer at sea ($p < 0.01$) than Wilson's Storm Petrel (Fig. 19 and 20). For the Grey-backed Storm Petrel, three sojourns at sea lasted 4.0 ± 3.6 days (range 1-8 days).

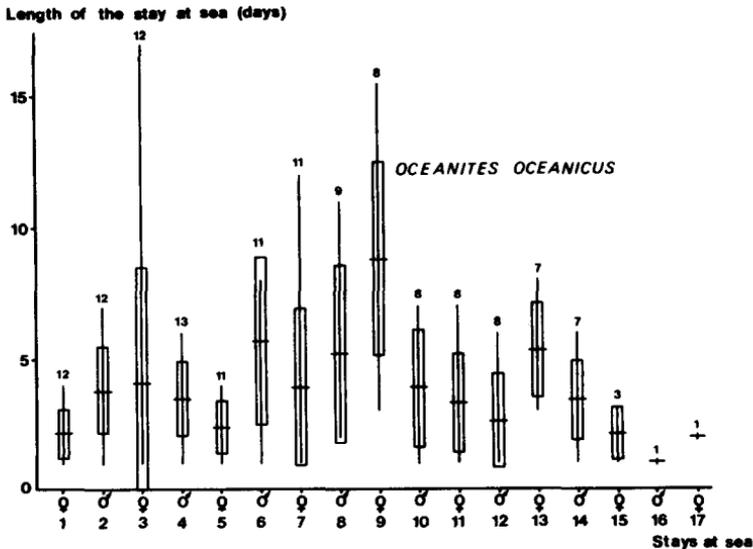
The eggs hatched in the first half of February for *Fregatta tropica* and *Garrodia nereis* and during the whole of February for *Oceanites oceanicus* (Table 22). The total incubation period differed between species, but with the many desertions allowed for, the actual incubation times were very similar. For Wilson's Storm Petrel, the average of 49.7 ± 5.4 days of total incubation minus 14.0 ± 7.0 days of desertions gave an actual incubation period of 35.7 ± 1.8 days (6 nests). A highly significant correlation ($r = 0.99$, $n = 6$) exists

TABLE 25 — Incubation shifts and egg desertions in *Oceanites oceanicus* and *Fregetta tropica*

	Length of stay in burrow (days)		Length of desertion (days)		Desertion frequency (per cent)	
	<i>O. oceanicus</i>	<i>F. tropica</i>	<i>O. oceanicus</i>	<i>F. tropica</i>	<i>O. oceanicus</i>	<i>F. tropica</i>
First shift (♀)						
Mean ± S.D.	0.6 ± 0.2	1.7 ± 0.6	0.6 ± 0.9	4.7 ± 2.1	41.2	100
Range (n)	0.5-1 (19)	1-2 ⁷ (3)	0-3 (17)	3-7 (3)		
Second shift (♂)						
Mean ± S.D.	1.8 ± 0.8	3.7 ± 2.9	1.3 ± 1.4	2.3 ± 0.6	66.7	100
Range (n)	1-3 ⁷ (16)	2-7 ⁷ (3)	0-5 (15)	2-3 (3)		
Third shift (♀)						
Mean ± S.D.	1.4 ± 0.6	3.7 ± 1.2	1.1 ± 1.8	2.7 ± 1.2	50.0	100
Range (n)	1-3 ⁷ (14)	3-5 ⁷ (3)	0-6 (14)	2-4 (3)		
Fourth shift (♂)						
Mean ± S.D.	2.4 ± 1.3	3.5 ± 1.0	0.3 ± 0.5	4 (1)	25.0	100
Range (n)	1-4 ⁷ (13)	3-5 ⁷ (3)	0-1 (12)			
Fifth shift (♀)						
Mean ± S.D.	2.2 ± 0.9	3.8 ± 1.0	1.5 ± 2.4	1.3 ± 1.2	50.0	67
Range (n)	1-3 ⁷ (12)	3-5 ⁷ (3)	0-8 (14)	0-2 (3)		
Sixth shift (♂)						
Mean ± S.D.	1.9 ± 0.9	3.3 ± 1.5	0.6 ± 0.7	3.7 ± 3.8	50.0	100
Range (n)	1-3 ⁷ (14)	2-5 ⁷ (3)	0-2 (14)	1-8 (3)		
Seventh shift (♀)						
Mean ± S.D.	2.0 ± 0.7	4.3 ± 2.1	1.2 ± 1.6	0 (2)	53.8	0
Range (n)	1-3 ⁷ (12)	2-6 ⁷ (3)	0-5 (13)			
Eighth shift (♂)						
Mean ± S.D.	1.8 ± 0.9	3.5	1.1 ± 1.8	2.5	42.9	50
Range (n)	1-3 ⁷ (12)	3-4 (2)	0-6 (14)	0-5 (2)		
Ninth shift (♀)						
Mean ± S.D.	2.3 ± 0.8	4.0	1.9 ± 2.5	1.0	58.3	100
Range (n)	1-4 ⁷ (10)	3-5 (2)	0-7 (12)	(2)		
Tenth shift (♂)						
Mean ± S.D.	2.2 ± 1.0	3.0	2.5 ± 2.8	4 (1)	63.6	100
Range (n)	1-3 ⁷ (9)	2-4 (2)	0-9 (11)			
Eleventh shift (♀)						
Mean ± S.D.	2.1 ± 0.9	3 (1)	1.0 ± 1.1	0 (1)	62.5	0
Range (n)	1-4 ⁷ (10)		0-3 (8)			
Twelfth shift (♂)						
Mean ± S.D.	1.8 ± 1.1	2 (1)	1.6 ± 1.3	0 (1)	77.7	0
Range (n)	1-4 ⁷ (9)		0-4 (9)			
Thirteenth shift (♀)						
Mean ± S.D.	1.6 ± 0.7	-	1.9 ± 1.6	-	77.7	-
Range (n)	1-3 ⁷ (9)		0-4 (9)			
Fourteenth shift (♂)						
Mean ± S.D.	1.3 ± 0.7	-	1.0 ± 1.7	-	50.0	-
Range (n)	1-3 ⁷ (9)		0-5 (8)			
Fifteenth shift (♀)						
Mean ± S.D.	2.0 ± 0.9	-	0.9 ± 1.2	-	50.0	-
Range (n)	1-3 ⁷ (6)		0-3 (8)			
Sixteenth shift (♂)						
Mean ± S.D.	2.1 ± 0.7	-	1.2 ± 1.2	-	71.4	-
Range (n)	1-3 ⁷ (7)		0-3 (7)			
Seventeenth shift (♀)						
Mean ± S.D.	1.5 ± 0.8	-	2.8 ± 1.3	-	100	-
Range (n)	1-3 ⁷ (6)		1-4 (4)			
Eighteenth shift (♂)						
Mean ± S.D.	1.0	-	0.7 ± 0.6	-	66.7	-
Range (n)	(2)		0-1 ⁷ (3)			
Nineteenth shift (♀)						
Mean	1.5	-	1.0	-	100	-
Range (n)	1-2 (2)		(2)			
Twentieth shift (♂)						
Mean	1.0	-	1	-	100	-
(n)	(2)		(1)			
Twenty-first shift (♀)						
Mean	2.5	-	1	-	100	-
Range (n)	2-3 (2)		(1)			
Twenty-second shift (♂)						
Mean	1	-	0	-	0	-
(n)	(1)		(1)			
Twenty-third shift (♀)						
Mean	1	-	0	-	0	-
(n)	(1)		(1)			

TABLE 26 — Incubation schedule in *Oceanites oceanicus* and *Fregetta tropica*

	<i>O. oceanicus</i>	<i>F. tropica</i>
INCUBATION		
Mean length of a shift (days)		
both sexes		
Mean \pm S.D.	1.8 \pm 0.9	3.7 \pm 1.4
Range (n)	0.5-4(197)	1-7(37)
male		
Mean \pm S.D.	1.9 \pm 1.0	3.7 \pm 1.4
Range (n)	1-4(94)	2-7(18)
female		
Mean \pm S.D.	1.7 \pm 0.9	3.7 \pm 1.4
Range (n)	0.5-4(103)	1-6(19)
DESERTION		
Mean number of periods per nest		
Mean \pm S.D.	8.5 \pm 5.1	7
Range (n)	3-18(6)	(1)
Total length per nest (days)		
Mean \pm S.D.	14.0 \pm 7.0	22
Range (n)	6-26(6)	(1)
Mean length of a period (days)		
Mean \pm S.D.	1.7 \pm 1.1	3.1 \pm 1.9
Range (n)	1-6(48)	1-8(20)
Frequency of nest-reliefs with desertion (per cent)		
Mean \pm S.D.	52.4 \pm 20.4	70.3 \pm 19.4
Range (n)	26.7-85.7(6)	50.0-100.0(5)
STAYS AT SEA		
Mean length (days)		
both sexes		
Mean \pm S.D.	3.9 \pm 2.8	7.7 \pm 2.3
Range (n)	1-17(152)	4-13(23)
male		
Mean \pm S.D.	3.7 \pm 3.0	8.0 \pm 2.6
Range (n)	1-17(72)	4-13(11)
female		
Mean \pm S.D.	4.0 \pm 2.3	7.4 \pm 1.9
Range (n)	1-11(80)	4-10(12)

FIGURE 19 — Duration of sojourns at sea in *Oceanites oceanicus* throughout incubation. Mean \pm standard deviation, range and sample size

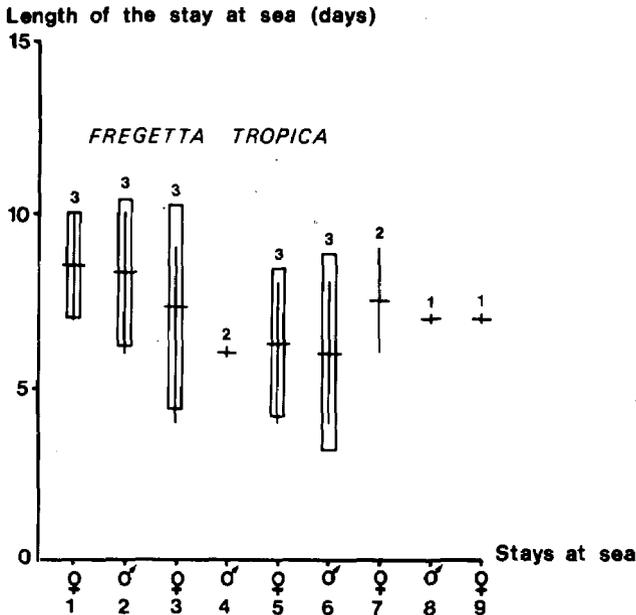


FIGURE 20 — Duration of sojourns at sea in *Fregetta tropica* throughout incubation. Mean \pm standard deviation, range and sample size

between the length of these desertions and the apparent total incubation period (Fig. 21). For the Black-bellied Storm Petrel, the only total incubation period recorded lasted 61 days. After subtracting 22 days of desertions, we obtained an actual incubation length of 39 days, which is similar to those obtained in other localities (Beck & Brown 1971). We have no information for the Grey-backed Storm Petrel.

As with procellarids, the thermic emancipation of the chicks was rapid, by the age of 1.8 days (range 1-3 for 4 chicks) for Wilson's Storm Petrel, by 0.7 days (range 12-24 hours for 3 chicks) for the Black-bellied Storm Petrel, and by 24 hours at the latest for the Grey-backed Storm Petrel (Despin *et al.* 1972).

Chick growth

As the dates of our stay on East Island did not coincide with the whole breeding period, chick growth was only partly studied. The first half of growth after hatching was studied for one chick of *Garrodia nereis* in 1970-1971 (Despin *et al.* 1972) and the first month of growth in three chicks each of *Oceanites oceanicus* and *Fregetta tropica* in 1981-1982. Maximum weight was not determined for any of the chicks (Fig. 22-25). Growth was particularly rapid in the Grey-backed Storm Petrel chick. In the first half of its rearing period,

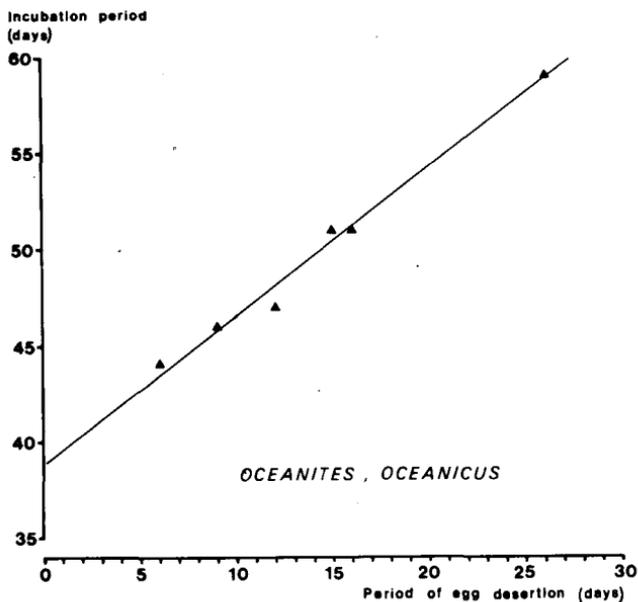


FIGURE 21 — Influence of egg desertions on the incubation period in *Oceanites oceanicus*. $y = 0.76x + 38.9$; $r = 0.99$; $n = 6$

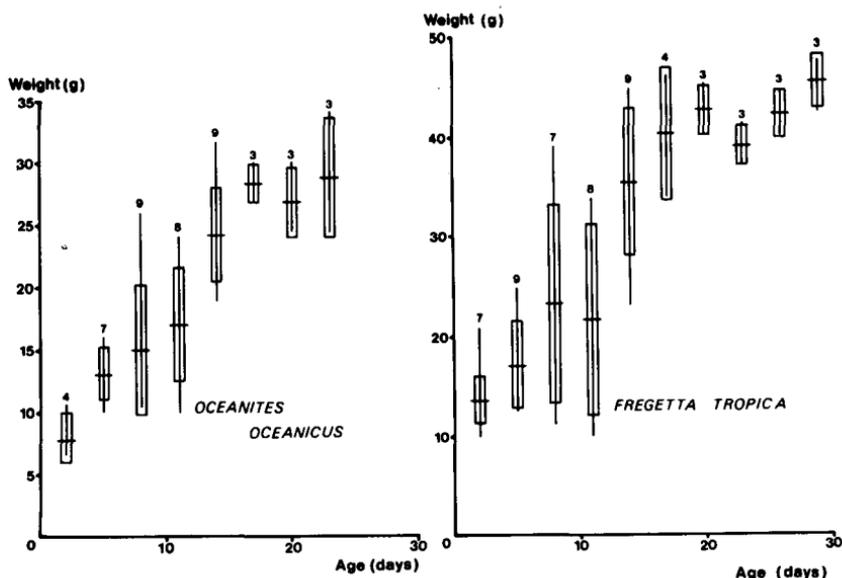


FIGURE 22 — Weight increase in *Oceanites oceanicus* chicks. Mean \pm standard deviation, range and sample size

FIGURE 23 — Weight increase in *Fregetta tropica* chicks. Mean \pm standard deviation, range and sample size

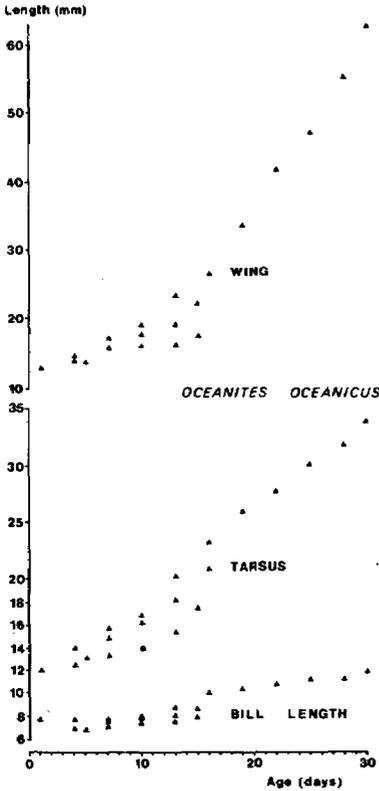


FIGURE 24 — Growth of wing, tarsus and bill length in *Oceanites oceanicus* chicks. Each point represents one measurement

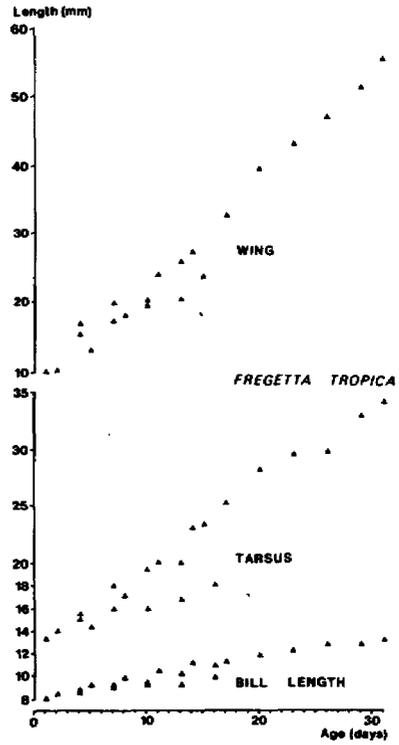


FIGURE 25 — Growth of wing, tarsus and bill length in *Fregatta tropica* chicks. Each point represents one measurement

its rate of weight gain in 3-day periods reached 39.1% compared with 30.9% in Wilson's Storm Petrel and 24.4% in the Black-bellied Storm Petrel. For this last species, weight gain was still very slow in the second 15 days after hatching, with an increase of only 2.2% compared with 19.6% during the same period for Wilson's Storm Petrel. As usual, the wing growth was slow at first, accelerating with the appearance of the vexilles of primaries. The culmen and tarsus grew rapidly during the first weeks of rearing.

Chick feeding was studied for Wilson's Storm Petrel and the Black-bellied Storm Petrel during the period of weight gain (Table 27). The average weight increase from day to day represented 19.4% of the chick weight of Wilson's Storm Petrel. The larger increase of 22.3% for the Black-bellied Storm Petrel corresponded with the proportionately and absolutely larger meals received by the chicks.

As during incubation, the Wilson's Storm Petrel spent shorter periods at sea (3.0 days) than the Black-bellied Storm Petrel (4.0 days), but they were more consistent in length during chick feeding. Both species returned to land more and more often during rearing, but especially the Black-bellied Storm Petrel. We have no equivalent data for the Grey-backed Storm Petrel.

DIVING PETRELS

Two species of diving petrels breed on the Crozet Islands, the South Georgian Diving Petrel (*Pelecanoides georgicus*) and the Common Diving Petrel (*P. urinator*, following the second edition of Peters' Check-list of Birds of the World — Jouanin & Mougin 1979). Table 28, which gives their measurements (partly from Prévost 1970, Despin *et al.* 1972), shows that the Common Diving Petrel is much larger than its relative, weighing 16.5% more, but its wing is only 2.5% longer and its culmen and tarsus are only 7.2% longer, although there is a considerable overlap of these measurements between the two species. The usual criteria for identification were tested (Table 29). The shape of the lower mandible appears highly unreliable. The coloration of the underwing coverts is a good criterion despite a small margin of error. Finally, the last criterion was found to be the most reliable: a black line on the back of the tarsus characterises *P. georgicus*, whereas black patches or a uniform blue coloration identifies *P. urinator*, as found on Kerguelen Islands (Milon & Jouanin 1953) and on South Georgia (Payne & Prince 1979).

Table 30 (partly from Despin *et al.* 1972, Derenne & Mougin 1976) shows the breeding cycle of these birds on Crozet archipelago. After totally deserting their colonies during the non-breeding season, diving petrels return to land at the end of winter, probably the end of August or the beginning of September for *P. urinator* and the end of September for *P. georgicus*. The breeding season lasts slightly longer than 5.5 months (170 days) for *P. urinator* and slightly less than 5 months (145 days) for *P. georgicus*. The difference of timing of the various stages of breeding between the two species becomes less as breeding progresses, and the well-synchronised fledging of chicks of both species occurs around mid-February (Fig. 26).

Reoccupation of burrows and pairing

A study of burrow visiting during pairing showed that *P. georgicus* is much less on land during the day than *P. urinator*. In the month before laying, an average of 3.6% of burrows were occupied by *P. georgicus* during the day, compared with 11.8% for *P. urinator*. In the Common Diving Petrel, the rate of burrow visiting was low until the 25th day before laying, when it increased progressively until the 6th day before laying (from $11.7 \pm 16.2\%$ to $18.1 \pm 11.7\%$ in 5-day periods). It then decreased suddenly in the last five days of pairing ($7.8 \pm 5.3\%$), corresponding to the prelaying exodus of at least one sex. Burrows were rarely occupied at this stage, and by only one bird.

No laying occurred in 20% of the 25 monitored burrows of *P. georgicus* and in 12% of the 41 of *P. urinator*. Each burrow of *P. georgicus* was visited by an average of 2.2 ± 0.7 birds (range 2-4 for 18 burrows) and each burrow of *P. urinator* by an average of 2.3 ± 0.7 birds (range 2-4 for 21 burrows). At the end of the prelaying exodus, the females of both species usually returned to land on the night before laying.

TABLE 27 — Chick-feeding pattern in *Oceanites oceanicus* and *Fregatta tropica*

Period of increase in weight		<i>O.oceanicus</i>	<i>F.tropica</i>
Number of chicks weighed		3	3
Number of weighings		45	51
Number of nights with visits (percent of total number of nights studied)	Mean \pm S.D. Range	55.8 \pm 2.2 54.6-56.3	44.1 \pm 8.5 38.5-53.9
Interval between meals (days)	Mean \pm S.D. Range	1.49 \pm 0.07 1.41-1.53	2.03 \pm 0.41 1.56-2.32
Weight increase per 24 hours when the chick is fed (g)	Mean \pm S.D. Range (n)	4.4 \pm 2.8 0-11(25)	6.6 \pm 3.6 1-16.5(22)

TABLE 28 — Weights (g) and measurements (mm) of diving petrels

		<i>P.georgicus</i>	<i>P.urinator</i>
Weight	Mean \pm S.D.	121 \pm 13	141 \pm 13
	Range (n)	90-150(71)	105-165(52)
Wing length	Mean \pm S.D.	119 \pm 5	122 \pm 4
	Range (n)	106-129(35)	114-129(54)
Culmen length	Mean \pm S.D.	15.3 \pm 0.8	16.4 \pm 0.7
	Range (n)	13.8-16.8(35)	14.0-18.0(54)
Culmen width	Mean \pm S.D.	9.3 \pm 0.5	9.3 \pm 0.6
	Range (n)	8.5-10.5(23)	8.5-10.5(33)
Tarsus length	Mean \pm S.D.	25.0 \pm 0.9	26.8 \pm 1.0
	Range (n)	23.0-26.5(35)	25.3-29.0(54)

TABLE 29 — Identification criteria for *Pelecanoides georgicus* and *P. urinator*

	<u>P.georgicus</u>	<u>P.urinator</u>
<u>Lower mandible</u>		
Number of birds studied	23	37
Rami parallel (percent)	0	43.2
Rami converging (percent)	100	56.8
<u>Underwing coverts</u>		
Number of birds studied	23	42
Grey (percent)	4.3	100
White (percent)	95.7	0
<u>Posterior part of tarsus</u>		
Number of birds studied	23	36
Black line (percent)	100	0
Black spot (percent)	0	58.3
No black (percent)	0	41.7

TABLE 30 — Timing and duration of events during the breeding cycle of the diving petrels

	<u>P.georgicus</u>	<u>P.urinator</u>
First returns on land	22 sep 81	before 19 sep 81
Length of period (days)	60	>40
Laying period		
Mean \pm S.D.	18 nov 81 \pm 11	27 oct 81 \pm 12
Range (n)	29 oct -8dec (18)	5 oct -24 nov (33)
Period from laying to hatching (days)		
Mean \pm S.D.	47.1 \pm 3.0	55.5 \pm 3.6
Range (n)	44-52(7)	49-63(16)
Real incubation period (days)	46	50-51
Hatching period		
Mean \pm S.D.	25 dec 70-20 jan 71	20 dec 81 \pm 11
Range (n)	30 dec 81 \pm 11 14 dec - 15 jan (11)	30 nov -11 jan (24)
Fledging period (days)		
Mean \pm S.D.	50.3 \pm 2.7	53.6 \pm 3.9
Range (n)	47-54(8)	47-59(10)
Departure of fledglings from the colony	16-17 feb 71 (2) 17 feb -22 mar 74	7 feb 82 \pm 10
Mean \pm S.D.	12 feb 82 \pm 11	25 jan -2 mar (11)
Range (n)	31 jan - 3 mar (6)	

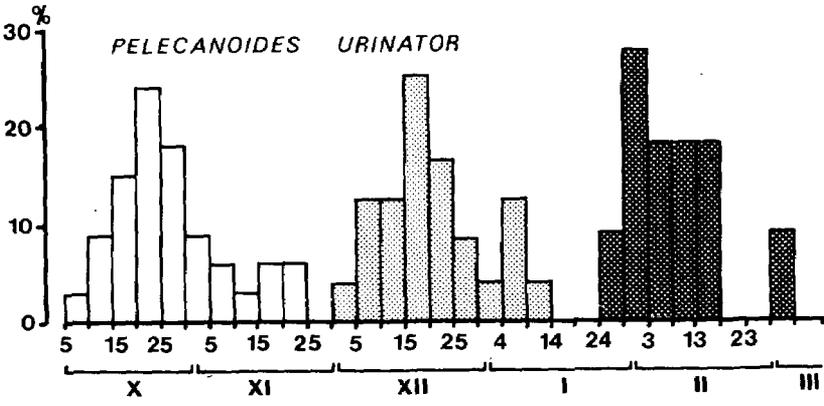
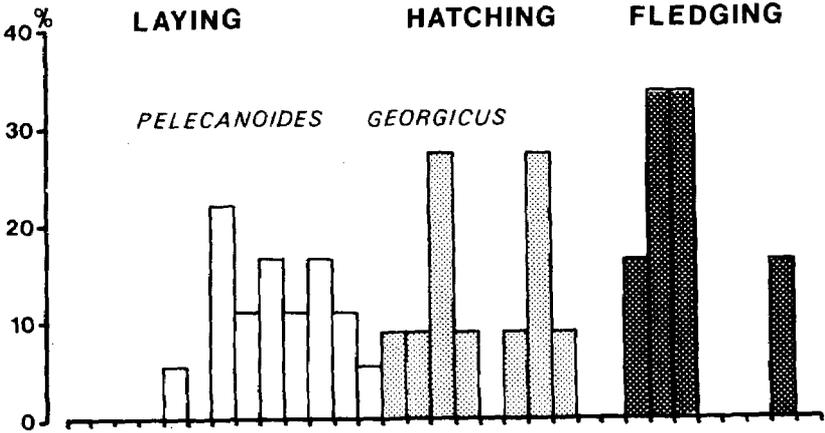


FIGURE 26 — Timing of events during the breeding cycle of *Pelecanoides georgicus* compared with *Pelecanoides urinator*

Laying

Common Diving Petrels laid, on average, 22 days before South Georgian Diving Petrels (Table 29 and Fig. 26). This was a significant difference ($t = 6.43$, $p < 0.001$) in spite of an overlap of 27 days. The laying period was long for both species (51 days for *P. urinator* and 41 days for *P. georgicus*). The laying date did not seem to influence the success of the egg in *P. georgicus*. In this species, 11 eggs that were abandoned were laid on 18 November ± 13 days (29 October-8 December) at the same date — 18 November ± 9 days (7-26 November) — as 7 eggs which were due to hatch.

The egg measurements for the two species (partly from Despin *et al.* 1972) did not differ significantly (Table 31). Thus, the ratio of egg weight to adult weight was smaller for the bigger *P. urinator* (15.7%) than for the lighter *P. georgicus* (17.4%). In both cases, however, the values were relatively low for burrowing Procellariiformes of such a small size.

Incubation

The incubation shifts were very different between the two species, being much shorter and more numerous ($t = 11.6$, $p < 0.001$) in *P. urinator* than in *P. georgicus*. The length of the shifts remained the same during all incubation, and in both species the sexes shared the duties equally. Temporary egg desertions were not common and were fewer in *P. georgicus* than in *P. urinator* (Table 32). Thus, the changing of partners on the egg was well synchronised.

Table 30 shows the hatching dates of the two diving petrels of Crozet archipelago. Hatching was more synchronised between the species than laying, only 10 days separating the average dates of hatching. For both species the hatching period was rather long, 33 days for *P. georgicus* and 43 days for *P. urinator*, with a considerable overlap of 29 days between the two species. As with laying, hatching was evenly distributed over the whole period with slightly more hatchings taking place in the early stages. The date of hatching appeared to have a large influence on the subsequent fate of the chicks, in contrast with the date of laying. *P. georgicus* chicks which eventually fledged hatched on average 14 days before those that did not — on 24 December ± 9 days (from 14 December to 10 January for 6 birds) compared with 7 January ± 9 days (from 21 December to 15 January for 5 birds). This was also true for *P. urinator*, where the interval measured 12 days, from 14 December ± 6 days (from 30 November to 21 December for 11 chicks) to 26 December ± 12 days (from 7 December to 11 January for 13 chicks).

The average total apparent incubation periods for the two species (47.1 days for *P. georgicus* and 55.5 days for *P. urinator*) were significantly different ($t = 5.39$, $p < 0.001$), although the actual incubation periods were similar. Desertions making up approximately 2.1% of the total apparent incubation period for the South Georgian Diving Petrel and 7.6-10.5% for the Common Diving Petrel, the actual incubation periods lasted about 46 days for the first species and 50-51 days for the second.

These species differed from the procellarids and storm petrels in that the thermic emancipation of their chicks was late, being 6.3 ± 2.0 days after hatching (range 3-9 days for 12 chicks) for *P. georgicus* and 11.6 ± 1.3 days after hatching (range 8-13 days for 17 chicks) for *P. urinator*. As they did during incubation, the adults took alternate shifts on the nest for an average

TABLE 31 — Weights (g) and measurements (mm) of diving petrel eggs

		<i>P.georgicus</i>	<i>P.urinator</i>
Weight	Mean \pm S.D.	21.1 \pm 1.7	22.1 \pm 2.0
	Range (n)	19-24(19)	19-26(19)
Length	Mean \pm S.D.	38.8 \pm 1.5	40.0 \pm 1.6
	Range (n)	36.2-41.7(32)	37.6-45.2(31)
Breadth	Mean \pm S.D.	31.6 \pm 1.0	31.6 \pm 1.0
	Range (n)	29.0-33.0(32)	29.3-34.0(31)

TABLE 32 — Incubation schedule in *Pelecanoides georgicus* and *P. urinator*

	<i>P.georgicus</i>	<i>P.urinator</i>
INCUBATION		
Mean length of a shift (days)		
both sexes		
Mean \pm S.D.	2.4 \pm 0.7	1.3 \pm 0.5
Range (n)	1-4(107)	1-3(165)
male		
Mean \pm S.D.	2.3 \pm 0.9	1.5 \pm 0.6
Range (n)	1-4(21)	1-3(38)
female		
Mean \pm S.D.	2.1 \pm 0.6	1.3 \pm 0.5
Range (n)	1-3(22)	1-3(38)
DESERTION		
Mean number of periods per nest		
Mean \pm S.D.	1	3.0 \pm 1.7
Range (n)	(2)	1-4(3)
Total length per nest (days)		
Mean \pm S.D.	1	4.3 \pm 3.5
Range (n)	(2)	1-8(3)
Mean length of a period (days)		
Mean \pm S.D.	1	1.4 \pm 1.0
Range (n)	(2)	1-4(9)
Frequency of nest-reliefs with desertion (per cent)		
Mean	4.9	6.2
Range (n)	4.5-5.3(2)	3.4-8.9(2)
STAYS AT SEA		
Mean length (days)		
both sexes		
Mean \pm S.D.	2.3 \pm 0.7	1.6 \pm 0.6
Range (n)	1-4(43)	1-5(76)
male		
Mean \pm S.D.	2.2 \pm 0.6	1.5 \pm 0.7
Range (n)	1-3(22)	1-4(38)
female		
Mean \pm S.D.	2.4 \pm 0.8	1.7 \pm 0.6
Range (n)	1-4(21)	1-5(38)

length of 1.1 ± 0.3 days (range 1-3 days for 64 shifts on 6 nests) for *P. urinator* and 1.5 ± 0.8 days (range 1-3 days for 13 shifts on 4 nests) for *P. georgicus*. The periods of time spent on land, which were shorter than during incubation, did not differ significantly between the two species.

Chick growth

The weight increases shown in Table 33 and in Figures 27 and 28 result from a study of 8 *P. georgicus* and 11 *P. urinator* chicks. The rates of increase in 3-day periods were $23.4 \pm 19.6\%$ for *P. georgicus* and $19.2 \pm 17.0\%$ for *P. urinator*. The chicks of both species reached the same maximum weight, 20% more than the adult weight for *P. georgicus* and 4% more for *P. urinator*, by the time they were three-quarters fledged for the first species and less than two-thirds fledged for the second. The subsequent loss of weight (29% of the maximum for *P. georgicus* and 22% for *P. urinator*) corresponds to a rate of decrease in 3-day periods of $3.0 \pm 4.1\%$ for *P. georgicus* and $3.1 \pm 0.8\%$ for *P. urinator*. The weight at fledging as a percentage of adult weight was the same for both species (82-86%). The growth of the wing (Fig. 29) was slow before the appearance of the primaries, then became more rapid, but adult measurements were not reached at fledging. The length increase, in periods of three days for the whole time on the nest, was approximately $13.2 \pm 6.6\%$ for *P. georgicus* and $11.8 \pm 6.7\%$ for *P. urinator*. The culmen and tarsus (Fig. 29) grew rapidly at the beginning of rearing and then slowed down until reaching adult size at fledging.

Table 34 gives the results of a chick-feeding study between hatching and fledging. For these chicks, the weight gains before and after thermic emancipation were separated. The chicks of both species were fed in a similar manner between hatching and emancipation. Between the emancipation of chicks and their reaching maximum weight, adults of both species returned to land less often but the meals were larger — the chicks of *P. georgicus* being fed less often than those of *P. urinator* but the size of their feeds being larger. Finally, during the period of weight loss, the adults returned to land even less often than before and decreased the size of the feeds. At this stage, each *P. georgicus* parent returned to land every 4.9 days and each *P. urinator* parent every 4.3 days.

Fledging

Table 30 and Figure 26 show the dates of fledging. Synchrony in breeding continued to improve between the two species until only 5 days separated the average fledging dates. But, as with laying and hatching, the dates of fledging were spread out, lasting 32 days for *P. georgicus* and 37 for *P. urinator*, with a considerable overlap of 31 days, these long periods appearing to be caused by a few late-fledging chicks. The total fledging period for both species was very similar (Table 30), approximately 50 days for *P. georgicus* and 54 days for *P. urinator*. Payne & Prince (1979), comparing their data with that of Despin *et al.* (1972), noticed rather large differences between the length of the fledging periods of *P. georgicus* on South Georgia and Crozet archipelago. Although such variability could be interpreted as different responses of populations exposed to different marine and climatic environments, these authors suggested that the data from Crozet were "atypical" or "based on a misidentification". However, the 1980-1981 data confirm the findings of Despin *et al.* (1972).

TABLE 33 — Weight growth in diving petrel chicks

		<i>P. georgicus</i>	<i>P. urinator</i>
<u>Weight at birth</u>			
Weight (g)	Mean \pm S.D. Range (n)	14.8 \pm 0.8 14.0-16.0 (5)	15.5 \pm 1.0 14.0-17.0 (9)
Percent adult weight		12.2	11.0
<u>Maximum weight</u>			
Weight (g)	Mean \pm S.D. Range (n)	145.4 \pm 21.7 122-175 (8)	146.9 \pm 21.7 122-184 (11)
Percent adult weight		120.2	104.2
Age at peak weight (days)	Mean \pm S.D. Range (n)	37.9 \pm 5.4 30-47 (8)	33.7 \pm 4.9 28-42 (11)
<u>Weight at fledging</u>			
Weight (g)	Mean \pm S.D. Range (n)	103.5 \pm 23.5 82-155 (8)	115.0 \pm 23.1 86-148 (11)
Percent adult weight		85.5	81.6

TABLE 34 — Chick-feeding pattern in diving petrels

		<i>P. georgicus</i>	<i>P. urinator</i>
<u>Period of increase in weight</u>			
-Before emancipation			
Number of chicks weighed		8	11
Number of weighings		38	105
Number of nights with visits (percent of total number of nights studied)	Mean \pm S.D. Range	85.6 \pm 17.4 57.1-100.0	80.3 \pm 10.9 58.3-100.0
Interval between meals (days)	Mean \pm S.D. Range	0.80 \pm 0.37 0.50-1.45	0.91 \pm 0.23 0.50-1.41
Weight increase per 24 hours when the chick is fed (g)	Mean \pm S.D. Range (n)	4.8 \pm 4.5 0-20 (31)	5.3 \pm 4.8 0-32 (84)
-After emancipation			
Number of chicks weighed		6	11
Number of weighings		167	249
Number of nights with visits (percent of total number of nights studied)	Mean \pm S.D. Range	61.5 \pm 5.5 54.6-70.4	68.6 \pm 4.9 60.0-75.0
Interval between meals (days)	Mean \pm S.D. Range	1.33 \pm 0.15 1.10-1.53	1.14 \pm 0.11 1.00-1.36
Weight increase per 24 hours when the chick is fed (g)	Mean \pm S.D. Range (n)	11.2 \pm 8.7 0-39 (102)	8.9 \pm 6.7 0-29 (170)
<u>Period of decrease in weight</u>			
Number of chicks weighed		5	11
Number of weighings		61	210
Number of nights with visits (percent of total number of nights studied)	Mean \pm S.D. Range	37.3 \pm 5.5 33.3-44.4	41.7 \pm 6.9 31.3-52.0
Interval between meals (days)	Mean \pm S.D. Range	2.44 \pm 0.38 1.96-2.72	2.17 \pm 0.42 1.63-2.93
Weight increase per 24 hours when the chick is fed (g)	Mean \pm S.D. Range (n)	10.1 \pm 9.9 0-31 (23)	4.4 \pm 4.2 0-20 (89)
<u>Total growth period</u>			
Number of chicks weighed		5	11
Number of weighings		225	564
Number of nights with visits (percent of total number of nights studied)	Mean \pm S.D. Range	57.4 \pm 2.4 54.2-60.0	60.7 \pm 3.1 56.5-64.6
Interval between meals (days)	Mean \pm S.D. Range	1.44 \pm 0.08 1.36-1.55	1.34 \pm 0.09 1.23-1.47
Weight increase per 24 hours when the chick is fed (g)	Mean \pm S.D. Range (n)	9.9 \pm 8.5 0-39 (156)	6.9 \pm 6.0 0-29 (343)
Last meal (nights before fledging)	Mean \pm S.D. Range (n)	2.2 \pm 0.8 1-3 (5)	3.9 \pm 1.5 1-5 (8)

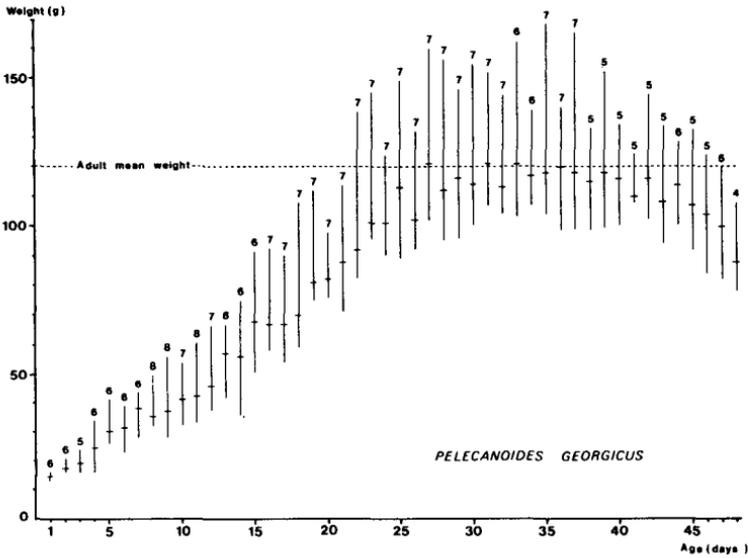


FIGURE 27 — Weight increase in *Pelecanoides georgicus* chicks. Mean, range and sample size

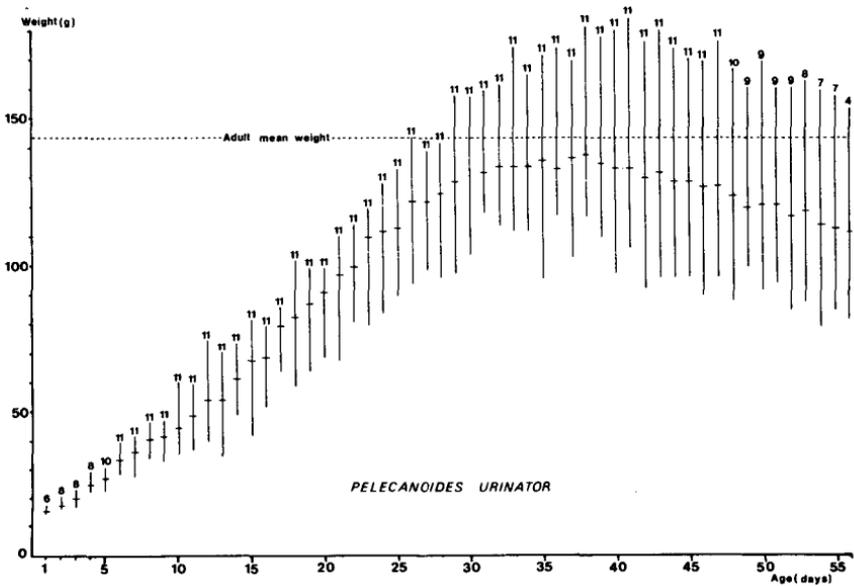


FIGURE 28 — Weight increase in *Pelecanoides urinator* chicks. Mean, range and sample size

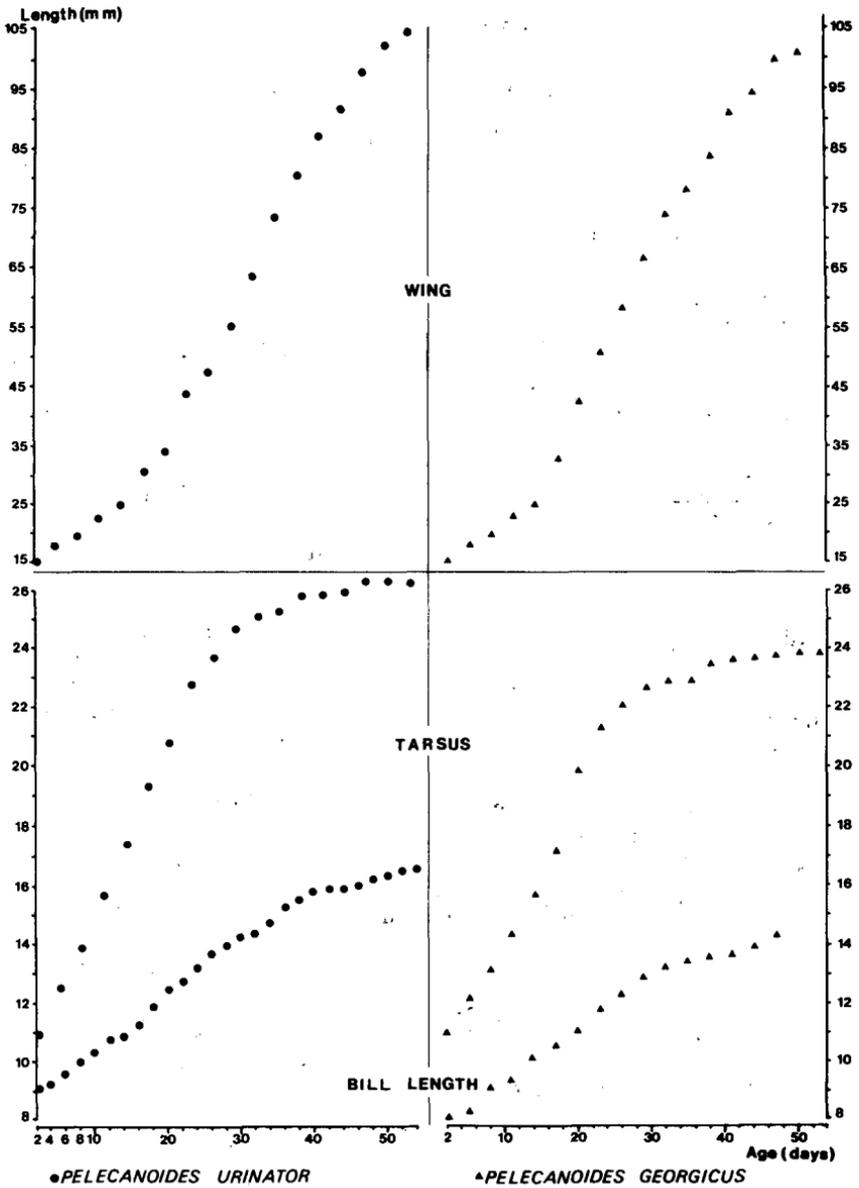


FIGURE 29 — Growth of wing, tarsus and bill length in *Pelecanoides georgicus* and *P. urinator* chicks. Mean points

DISCUSSION

Among the many points highlighted by these data, we have chosen five for discussion.

Abundance cycles in the colonies during pairing

Daily inspection of burrows showed that, during nest reoccupation, the return to land of certain petrels was cyclic. These rhythmic visits were particularly marked for Salvin's Prion, the Black-bellied Storm Petrel and the Grey-backed Storm Petrel, where two abundance peaks were separated by an average interval of 7.4 days, 15.5 days and 16.5 days respectively. The White-chinned Petrel had a similar but less marked abundance pattern. For the other species studied, the numbers observed every night were rather constant.

In these colonies, we made daily 10-minute point counts one hour after sunset, by which time all species were present on land. In each point count (always from the same place) we assessed how many birds of each species were calling. These two methods — inspection of burrows and point counts — used together showed that bird numbers in burrows and vocal activity in the colonies were closely linked. The point count results, partly shown in Figure 30, confirm a cyclic activity for certain species.

Why do these species return to land in such a synchronised way? Do environmental factors influence them? A clear night with a full moon could, for example, stimulate them to return to land by making the colonies or burrows easier to see or, on the contrary, could discourage them by allowing greater skua activity in the colonies. In fact, the returns to land did not correlate with moon or clouds. They did not correlate with weather conditions either: the petrels returned to land independently of wind, rain or fog. Bartle (1968) came to the same conclusions when working on *Pterodroma pycrofti* in New Zealand.

The species that returned cyclically seemed to follow a precise rhythm, perhaps induced by physiological factors. It is hard to believe that birds from the same colony satisfy their hunger simultaneously and return to the colony together or that they stay together at sea in groups. For *Fregetta tropica* the frequency of these rhythms increased during pairing and gradually matched their rhythms of incubation shifts.

We know the importance of physiological and social factors in these birds' breeding biology (Craig 1911, 1913, Darling 1938) and so it is possible that certain species begin to synchronise their shift cycles even before laying. These return-to-land rhythms may be part of a developing synchrony in their social life which facilitates the meeting of adult pairs and pairing of young birds.

Temporary egg desertion

Temporary egg desertions during incubation in many species of procellariiformes are known to occur between the departure of one incubating parent at the end of a shift and the return to land of its partner (for references, see Boersma & Wheelwright 1979), and the embryo survival, even at low temperatures, is a remarkable physiological adaptation. Most of the petrels

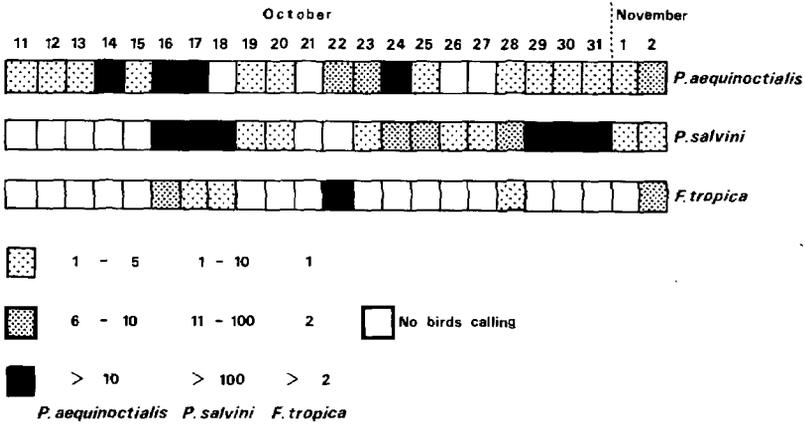


FIGURE 30 — Ten-minute point count results from a mixed petrel colony on East Island (mid-October to beginning of November). Classes represent the number of calling individuals

breeding on the Crozet Islands have this characteristic because the climate is relatively mild and, in fact, these temporary desertions are more limited in the more severe climates, as shown by the example of Wilson's Storm Petrel: 14 days on the Crozet Islands (45°S), 4.1 days on Signy Island (60°S, Beck & Brown 1972) and 1.4 days in Adélie Land (68°S, Lacan 1971).

The cumulated length of the desertions during incubation did not seem to influence hatching success. On the contrary, the embryo survival depends on the timing of the desertions — well-developed embryos suffer more than newly laid eggs from the absence of incubating birds — and on the length of the individual periods — on the Crozet Islands 11 days of desertion early in incubation did not prevent hatching for *Pterodroma brevirostris*, but it is the longest egg desertion known for procellariiformes.

Boersma & Wheelwright (1979) have reviewed different aspects of the meaning of egg desertion in procellariiformes. From our Crozet data, we can compare the frequency of shifts with egg desertions and the frequency of egg desertions during two breeding seasons for nine species of burrowing petrels (Table 35). These comparisons show that we have to allow for such factors as the size of the bird and its flying capacity when we consider egg desertion in petrels.

Among the species of Table 35, the only ones seen flying during gales in the southern oceans are the diving petrels. They are birds of coastal and continental waters with a powerful and linear flight pattern, and they rarely desert their eggs. Except for the diving petrels, small petrels are more likely than larger ones to desert their eggs during incubation. They are also more likely to be prevented from returning to their colonies by storms and, especially

because of their size, less capable of prolonged fasts when incubating. In contrast, *Procellaria aequinoctialis*, one of the largest burrowing procellariiformes, never deserts its egg. Probably because of its large size, the incubating bird can fast for a long period when the return of its partner is delayed. Finally in *Pterodroma brevirostris*, which is one-third smaller than *P. aequinoctialis*, egg desertion varies from year to year: it occurred often in 1981-1982 but not at all in 1968-1969. The weather records during incubation were average for both years, suggesting that the difference between the two cycles was caused by foraging difficulties and not by weather. Because of these difficulties in 1981-1982, the Kerguelen Petrels spent more time at sea and they could do this by means of egg desertion between shifts rather than by lengthening the incubation shifts. Temporary egg desertions can allow for lengthy sojourns at sea which may permit longer foraging times. In fact, they play the part of a "safety device" useful when the foraging birds are unsuccessful or prevented from coming back to land by bad weather, and when the incubating birds, unable to fast any longer, are obliged to leave the nest.

Competition for burrows

Some petrels studied on the Crozet Islands did not breed in haphazardly chosen burrows but, during the prelaying stage, showed preferences for certain burrows. As a result, favoured burrows in which an egg was ultimately laid often attracted more birds than those in which no egg was laid (Table 36). This attraction for certain burrows suggests competition for the breeding sites. Two or more successive layings were noted in some burrows, each taking place after the eviction of the former egg and sometimes of the incubating adults as well.

TABLE 35 — Egg-desertion frequencies and schedules in burrowing procellariiformes

	Frequency of shifts with egg desertion (%)	Mean cumulative egg desertion period (days)	Mean duration of a single egg desertion (days)	Maximum length of an egg desertion (with hatching success) (days)
<i>P. brevirostris</i>				
1968-1969	0	0	0	0
1981-1982	46.7	9.0	4.5	11
<i>P. mollis</i>	11.7	1.8	3.7	4
<i>H. caerulea</i>	43.3	5.6	2.9	5
<i>P. salvini</i>	41.2	4.8	1.9	5
<i>P. aequinoctialis</i>	0	0	0	0
<i>O. oceanicus</i>	52.4	14.0	1.7	6
<i>F. tropica</i>	70.3	22.0	3.1	8
<i>P. georgicus</i>	4.9	1.0	1.0	1
<i>P. urinator</i>	6.2	4.3	1.4	4

TABLE 36 — Nest reoccupation and nest selection in burrowing procellariiformes

	Number of birds visiting nests		Number of nests visited		
	with subsequent laying	without subsequent laying	without subsequent laying (%)	with 2 successive layings (%)	with 3 successive layings (%)
<i>P. mollis</i>	3.71 ± 1.53 (17)	2.07 ± 1.33 (15)	45.9 (32)	5.9 (17)	0
<i>P. brevirostris</i>	-	-	23.5 (34)	0	0
<i>P. salvini</i>	4.32 ± 2.01 (38)	3.00 ± 1.75 (20)	34.5 (58)	5.7 (53)	5.7 (53)
<i>P. aequinoctialis</i>	3.06 ± 2.01 (18)	3.29 ± 1.94 (13)	42.0 (31)	5.6 (18)	0
<i>O. oceanicus</i>	-	-	16.0 (25)	0	0
<i>F. tropica</i>	-	-	82.0 (17)	0	0

Comparison with other localities

Little has been published on the breeding biology of the burrowing petrels of the Crozet archipelago in other localities. However, a different subspecies of the Great-winged Petrel, *Pterodroma macroptera gouldi*, was studied in New Zealand (Imber 1976) where, despite breeding in the subtropical zone, laying occurs 6 weeks later than on the Crozet Islands. Feeding frequency of chicks is lower in New Zealand — 3.9 days compared with 3.25 days — but, despite this, fledging weight is higher (540 g versus 460 g). Results of the studies on the Black-bellied Storm Petrel (*Fregatta tropica*) and the Wilson's Storm Petrel (*Oceanites oceanicus exasperatus*) were reported by Beck & Brown (1971, 1972) from Signy Island, South Orkney Islands. For Wilson's Storm Petrel, even though our study was again of a different subspecies (*O. o. oceanicus*), no differences in breeding could be detected. In Adélie Land, Antarctica, where *O. o. exasperatus* also breeds, the breeding occurs a month earlier and the incubation shifts are half as long as on the Crozet or Signy Islands.

The diving petrels show important differences between the Crozet Islands and the other breeding localities. Prince & Payne (1979), comparing their South Georgian results for *P. urinator* and *P. georgicus* with preliminary studies made on the Crozet Islands, showed that the first one lays its egg at about the same time in both localities whereas the second is almost a month later in South Georgia than in the Crozet archipelago. In the colder locality, there is a very strong synchronisation of laying, especially with the first species. It seems that a more climatically severe nesting habitat causes the delay in the breeding cycle of one of the species. On both Crozet Islands and South Georgia, *P. urinator* nests on steep slopes near the sea whereas *P. georgicus* nests on the higher slopes. Thus, when this species' laying season starts on the Crozet Islands, in November, the colonies are still covered with snow in South Georgia. Thus, specific breeding habitat requirements determine the differences in breeding in this species, rather than food supply.



FIGURE 31 — A Kerguelen Petrel at the entrance of its burrow in a marshy area (Possession Island).
Photo: H. Weimerskirch



FIGURE 32 — A Grey Petrel at the entrance of its burrow among *Poa cookii* (Possession Island).

Photo: H. Weimerskirch

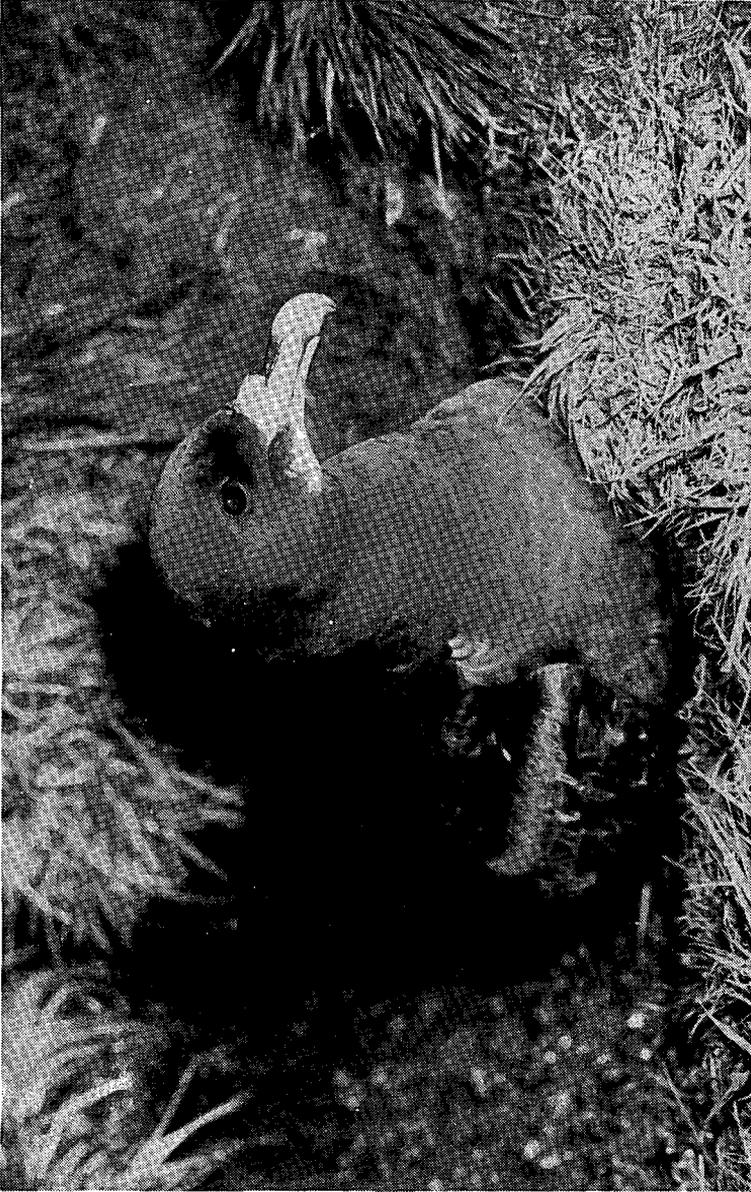


FIGURE 33 — A White-chinned Petrel at Possession Island.

Photo: H. Weimerskirch

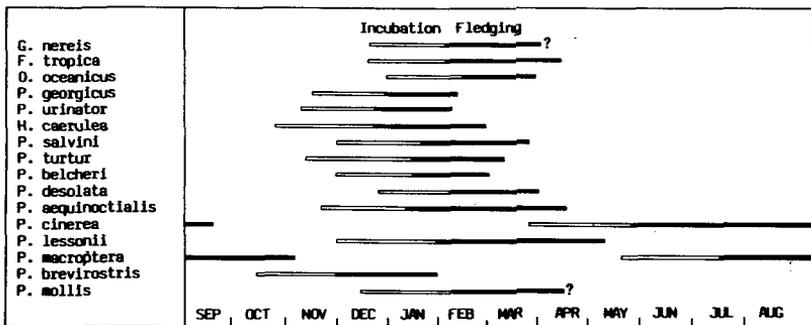


FIGURE 35 — Timing of the breeding season for the 16 burrowing procellariiformes of the Crozet Islands

around the Crozet Islands. Their food ranges therefore overlap broadly (Ridoux, unpubl.). At the present time, the only known feeding-related differences between the two species consist of the filtering device on the bill and the less pelagic sea distribution of *P. salvini*.

The three storm petrels breed at the same time of the year but have different breeding habitats and diets. *Garrodia nereis* is narrowly specialised for prospecting for floating algae on the Crozet shelf. *Fregetta tropica* concentrates over the continental slope, whereas *Oceanites oceanicus* is limited to the shelf (Stahl, unpubl.). This difference in habitat and diet is reflected in that the incubation shifts (Table 26) and the time between successive feeds to chicks (Table 27) are longest for the species which feeds furthest from the nesting grounds. The diets of the two larger storm petrels overlap slightly, but *F. tropica* feeds on larger prey than *O. oceanicus* (Ridoux, unpubl.).

Finally, although the two diving petrels breed at the same time, their incubation shifts and their feeding frequencies are very different (Tables 32 and 34). Observations at sea around the Crozet Islands show that *Pelecanoides georgicus* feeds further offshore than *P. urinator* because the first is observed mostly over the continental slope and the second mostly over the continental shelf. So, *P. georgicus* displays the longest feeding trips. In South Georgia the two species do not breed at the same time. This, as we have seen, may be due to nesting habitat segregation with snow covering the higher burrows of *P. georgicus*. Little information is available on where the diving petrels feed around South Georgia. If, taking advantage of the local temporal segregation, both species feed near the coast, that would explain why the chicks of *P. georgicus* grow faster in South Georgia than in the Crozet archipelago (45.5 days compared with 50.3 days). These results are in opposition with the conclusions of Payne & Prince (1979) and show that data from one locality cannot necessarily be applied to another.

Preliminary data about the diet of the petrels of the Crozet Islands (unpubl.) show on one hand that an important overlap exists for closely related species and on the other that the same species may change diet from one island to another. Thus generally it appears that the spatio-temporal factors are at least as important as diet. Indeed food seems mainly implicated indirectly (through latitude, temperature, salinity, i.e. the masses of water). Ecological segregation in seabirds is not the result of a single factor but usually reflects several factors working together.

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SHORT NOTE

A Cattle Egret

On May 1985, I picked up a Cattle Egret on the Drake Flats, Waitotō Valley, South Westland, which appeared to have been recently taken by a Falcon. The whole neck and body were plucked, the feathering remaining only on the head and wings. All the plumage was white.

The bill was horn yellow at the tip, shading to deep yellow at the base; the iris was clear yellow; the legs were grey-green around the metatarsal joint, shading to charcoal lower down; top of toes blackish, undersides pale sage-green; claws blackish. Although this was about 22 km in a direct line from the sea coast and where Hereford cattle were grazed, three other egrets were feeding 7 km further up the valley (at the Donald Flats), where there were no stock.

PETER CHILD, *10 Royal Terrace, Alexandra*

THE BIRDS OF THE NOISES ISLANDS, HAURAKI GULF

By DUNCAN M. CUNNINGHAM and PHILIP J. MOORS

ABSTRACT

An annotated list of the 52 species of bird seen on and around the Noises Islands in Hauraki Gulf is presented, incorporating information from unpublished field notes from the 1930s onwards and the authors' own observations, which began in 1977. Eight of the 20 species of seabird and 13 of the 32 species of land bird breed at the islands. The only breeding species of native forest bird are Grey Warblers, Fantails and Silvereyes. We review the breeding history of White-faced Storm Petrels and Spotted Shags.

Analysis of Australasian Harrier pellets showed that passerines were the most frequent prey and that carrion was taken from islands at least 2.3 km from the Noises. The contents of 13 Blackbird and four Song Thrush gizzards were also analysed. Houpara fruit was present in 12 Blackbird gizzards and insects (mainly beetles) in eight. The thrushes had fed mainly on small snails and insects.

INTRODUCTION

The Noises are a group of small islands on the western side of the Hauraki Gulf about 24 km north-east of Auckland city (Fig. 1). Being reasonably close to Auckland they have often been visited by ornithologists, mainly to observe seabirds. Some of these observations have been published, but many more have remained in field notebooks. We have been fortunate in being given access to much of this unpublished material to supplement and compare with our own observations between 1977 and 1983.

Our information was collected during regular trips to the Noises Islands to study Norway rats (*Rattus norvegicus*), which colonised the group in 1956-57 (Moors 1985, in press). Our study of birds was part of a collaborative investigation in which scientists from the New Zealand Wildlife Service and Botany and Entomology Divisions, Department of Scientific and Industrial Research, studied the rats, birds, insects, vegetation and soils of the islands. The aims of our study were to establish the composition of the past and present avifauna of the Noises Islands and to collect information on breeding and diet.

DESCRIPTION OF THE NOISES ISLANDS

The main islands in the Noises group (36°42'S, 174°58'E; Fig. 1) are Orata (21.8 ha) (Fig. 2), Motuhoropapa (9.5 ha) (Fig. 3), Maria (2.0 ha) and the David Rocks (2.0 ha). In addition there are five islets, the largest being Scott (0.6 ha). The islands are composed mainly of argillite and greywacke

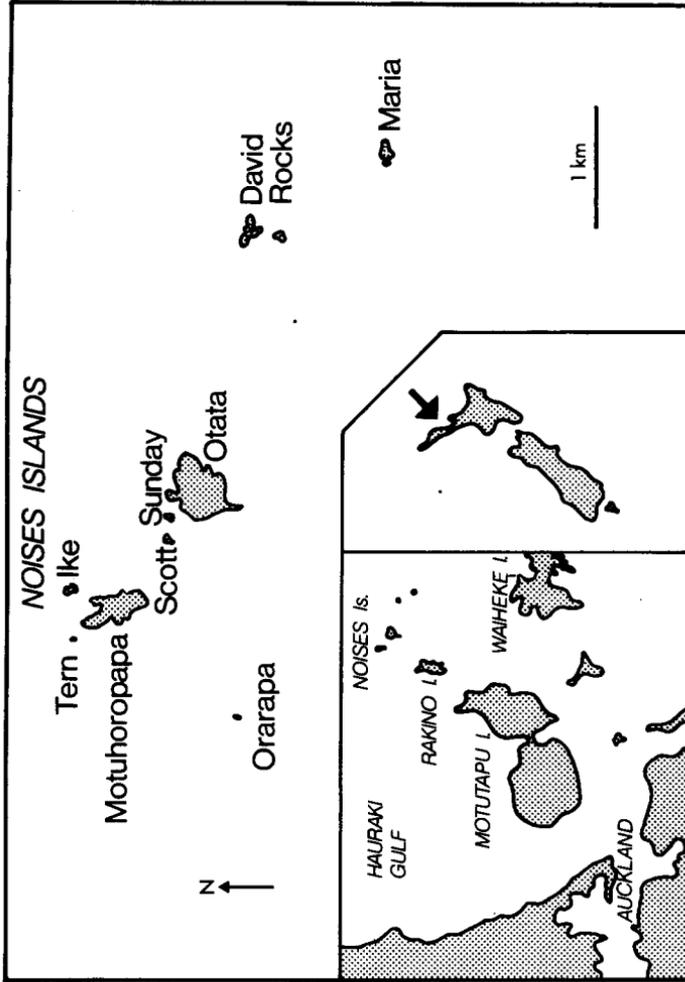


FIGURE 1 — The Noises Islands and their location in Hauraki Gulf

(Mayer 1968). The shorelines are heavily indented and have substantial rock platforms exposed at low tide. Sand and shingle beaches are present on Otata, Motuhoropapa and Scott. The islands all lack permanent fresh water, although rock pools and seepages provide temporary supplies after rain. A cottage on Otata was occupied for a decade or so until 1957 but is now used only for holidays. In summer Otata is often visited during the day by boating parties. The other islands are uninhabited and rarely landed on.

Otata is mostly covered with scrub and forest regenerating after a fire sometime between 1925 and 1930. Pohutukawa (*Metrosideros excelsa*) and karo (*Pittosporum crassifolium*) are now common around the edges of the island, often forming a closed canopy up to 15 m high. The major components of the regenerating scrub are mapou (*Myrsine australis*), coastal karamu (*Coprosma macrocarpa*), houpara (*Pseudopanax lessonii*) and mahoe (*Melicytus ramiflorus*). The scrub canopy is generally closed and 4-8 m high. On the north-western side of Otata lie two islets, Sunday and Scott. Both are covered with tall woody vegetation, mainly pohutukawa, karo and houpara.

Motuhoropapa Island, 700 m to the north-west of Otata, is covered with mature forest about 100 years old, typically 6-10 m high. The closed canopy consists mainly of pohutukawa, karo, houpara, wharangi (*Melicope ternata*), and mahoe. In the southern two-thirds of the island there is an understorey of kohekohe (*Dysoxylum spectabile*), and in the northern third one of houpara, wharangi and coastal karamu.

Tern Rock and Ike Island lie to the north and north-east of Motuhoropapa, respectively. Tern Rock is a very small islet about 10 m high supporting only four species of plant. Ike Island is larger and partly vegetated with 20 species, including pohutukawa, karo and stunted ngaio (*Myoporum laetum*). Orarapa is a tiny isolated stack 1.1 km south-west of Motuhoropapa capped with a prostrate vegetation mainly of taupata (*Coprosma repens*) and *Muehlenbeckia complexa*.

The David Rocks lie 1.8 km east of Otata and consist of five islets, four of which are joined at low tide. The separate islet lies about 100 m to the south of the main group. Vegetation covers about half of the total area and is mainly karo, houpara, taupata and boxthorn (*Lycium ferocissimum*). Pohutukawa is lacking.

Maria Island is 1.0 km south-east of the David Rocks. Here, too, pohutukawa is lacking, but there is a dense cover mainly of taupata and *Melicytus (Hymenanthera) novae-zelandiae*. Boxthorn has invaded the lower slopes, and bracken (*Pteridium esculentum*) covers the cleared top, where a navigation light was installed in 1953. The pea-vine (*Dipogon lignosus*) is throughout the bracken and many other open sites on the island and in some places is blanketing the low taupata canopy.

METHODS

Our bird information was collected during 34 trips to the Noises Islands between August 1977 and August 1983. There were no visits in March, May or July. Most observations were made by us in the course of the rat study and related projects, and sometimes these commitments limited the attention

which could be given to birds. We spent most time on Motuoropapa and Otata and their nearby islets, and so information for the David Rocks and Maria Island is less comprehensive. On each trip we noted new species and also the presence or absence of species previously recorded, together with data on abundance, food habits and breeding. We were able to confirm breeding more easily for seabirds than for land birds because seabird nests were usually more conspicuous or more readily discovered.

Moynihan & Imboden (in prep.) carried out an intensive programme of banding and censuses on Motuoropapa between December 1977 and March 1979 to collect information on the numbers and movements of forest passerines for comparison with mainland populations. We are grateful for permission to include some of their data in this paper.

Copies of unpublished field notes are held on Wildlife Service file WIL 30/3/35.

PREVIOUS ORNITHOLOGICAL VISITS TO THE NOISES ISLANDS

During pre-European times the Noises Islands were visited by the Maori to collect birds, presumably Grey-faced Petrels, and seafood (*New Zealand Herald*, 27 November 1866).

Table 1 lists the dates of all ornithological visits to the Noises Islands made before 1977 for which we have field notes or published references. The earliest specifically ornithological reference is by Falla (1932), who refers to Spotted Shags (*Stictocorbo punctatus*) nesting there in 1910.

Falla's later visits between 1918 and 1938 were also concerned with Spotted Shags nesting on Otata Island and the David Rocks and with White-faced Storm Petrels (*Pelagodroma marina*) breeding on Maria Island. His visits in the 1930s overlapped those of the Auckland University Field Club.

The Field Club made four day-trips to the Noises between 1933 and 1938, and on each occasion members recorded their observations in the Club's Trip Book. They landed on Otata on each trip but usually viewed the other islands only from their boat. The Spotted Shag colony on the David Rocks was checked on two trips. The account of the trip on 13 May 1933 contains a description of Otata's vegetation, still in the early stages of recovery from the fire several years previously (see Mason & Trevarthen 1950). The top of the island was thickly covered with bracken and tutu (*Coriaria arborea*) and extensively burrowed by rabbits (*Oryctolagus cuniculus*) and petrels. Sunday Island was also explored on this trip and found to be heavily burrowed by Grey-faced Petrels. Small burrows presumed to be of "stormy petrels" were seen during the next expedition on 23 June 1934. This is the only record we have found suggesting that storm petrels once bred or attempted to do so on Otata. The islands were visited again on 16 April 1935 but no bird observations were entered in the Trip Book. The description of the visit on 3 April 1938 concentrates on the Grey-faced Petrel colonies on Scott and Sunday Islands.

Fleming's (1940a) report of Spotted Shags breeding in October 1939 is the last record we have located until after the war. However, before the end of 1946, Cox (1946), Buddle (1951), and Sibson (1948a, b, unpubl.) had

TABLE 1 — Dates of visits to the Noises Islands between 1910 and 1971 for which we have found published or unpublished ornithological records

Date	Visitor	Island ¹	Source	Date	Visitor	Island	Source
1910	Falla	N	Falla 1932	21.12.48	Sibson	T,O,D	Sibson 1950, unpubl.
1923	Falla	O	Skegg unpubl. ²				
1925	Falla	O	Falla 1932	2.04.50	Davenport	O	Davenport 1951
1928	Falla	O	Falla 1932	23.07.53	Turbott	H,D	Turbott unpubl.
31.08.31	Falla	O,D	Falla 1932,	4.04.54	Macdonald	O	Turbott 1956
			Skegg unpubl.	Aug 1954	Moynihan	O	Turbott 1956
Nov 1932	Fleming	M	Fleming 1978	3.03.56	Turbott	O	Turbott 1956
13.05.33	AUFC ³	O,Su,D	AUFC Records	24.03.56	Turbott	O,D	Turbott 1956
2.12.33	Falla	M or D	Falla 1934	1957	Gillham	H,T,O, D,M	Gillham 1960, 1965
3.03.34	Falla	M or D	Falla 1934				
23.06.34	AUFC	O,D	AUFC Records	14.01.60	Brown	D,M	Brown unpubl.
31.12.34	Falla	M	Skegg unpubl.	Aug 1960	Burns	D,M?	Burns 1960
11.05.35	Turbott	D	Turbott 1956	26.11.60	Merton	D,M	Merton unpubl.
19.09.37	Buddle	D	Auck. Mus. Photo Coll.	1.07.61	Merton	M	Merton 1961
			AUFC Records	25.01.62	McDonald	M	Banding Records ⁴
3.04.38	AUFC	Sc,Su	Fleming	10.02.62	Sibson	M	Sibson unpubl.
1.05.38	Fleming	N	Fleming pers. comm.	17.11.62	Skegg	M,D,O, H,T	Skegg unpubl.
6.08.38	Fleming	Su,H,D	Fleming 1940b				
Oct 1939	Fleming	N	Fleming 1940a	9.03.63	Sibson	M,D	Sibson unpubl.
31.07.46	Cox	D	Cox 1946	20.04.83	Bishop	O	Bishop unpubl.
14.10.46	Buddle	D?	Auck. Mus. Photo Coll.	28.09.63	Merton	M,D,O,H	Merton unpubl.
			Sibson 1948, unpubl.	5.12.64	Merton	M	OSN2 Nest Records ⁵
1.12.46	Sibson	I,O,D	Sibson 1949, unpubl.	21.03.70	Millener	O,D	Millener 1970
11.11.47	Sibson	D	Auck. Mus. Photo Coll.	12.04.70	Millener	O,D	Millener 1970
				3.05.70	Gaunt	O	Gaunt pers. comm.
7.11.48	Buddle	D		11.12.71	Gaunt	O	Gaunt pers. comm.

1. N = Noises Islands
H = Motuhoropapa Island
T = Tern Rock
I = Ike Island
O = Otata Island
Sc = Scott Island
Su = Sunday Island
D = David Rocks
M = Maria Island

2. Copies of all unpublished material are in Wildlife Service file WIL 30/3/35.
3. Auckland University Field Club. Copies of the relevant pages of the Trip Book are in Wildlife Service file WIL 30/3/35.
4. Records of the New Zealand National Bird Banding Scheme.
5. Data from the Nest Record Scheme of the Ornithological Society of New Zealand.

all been to the islands and made observations on Spotted Shags and White-faced Storm Petrels. Many ornithologists visited the islands in the 1950s, and the discovery that Norway rats had colonised the islands led to increased interest during 1960-1964. A. McDonald (*in litt.*) noted severe rat predation on White-faced Storm Petrels on Maria Island and the David Rocks in late 1959, prompting him to organise a rat eradication campaign which Merton (unpubl. 1960, 1961, unpubl. 1963) continued until September 1963. Ornithological interest in the islands seems to have slackened after this, and the reports by Millener (1970) and J. Gaunt (*in litt.*) are the only ones we have found for the period 1964-1977.

ANNOTATED LIST OF BIRDS FROM THE NOISES ISLANDS

The 52 species of bird seen on or near the Noises Islands are listed in Table 2. The records are grouped into four periods, the first three corresponding to years when adequate historical information is available and the fourth to the time when we were making observations. The lists for 1923-1938 and 1946-1957 are dominated by species seen on Otata, where early visitors usually landed and spent most time.

The following annotated checklist contains information mostly collected between 1977 and 1983, supplemented where appropriate with earlier records of distribution and breeding.

TABLE 2 — History of distribution and breeding status of the birds of the Noises Islands, 1923-1983. The information presented for each period is condensed from the sources given in Table 1

Species	1923-1938	1946-1957	1960-1964	1977-1983
<u>A. Birds seen on the Noises Islands</u>				
Northern Blue Penguin	O		H*O*D M*	H*O*D*M*
Grey-faced Petrel	H*O*		O*	H*O* M*
White-faced Storm Petrel	M*	D*	D*M*	H M*
Northern Diving Petrel			D	H M*
Black Shag	O			H O
Pied Shag	O D M	O+	H O*D	H O*D
Little Shag		O		H O D M
Spotted Shag	O*D*	O*D*	H D*	H O*D M
White-faced Heron				H
Reef Heron	O			H O
Grey Duck				H
Australasian Harrier	O	H O D	H O M*	H*O *M
Brown Quail	O+	O+	O	
South Island Pied Oystercatcher				O
Variable Oystercatcher				O
Southern Black-backed Gull	O	O D*	H*O*D*M*	H*O*D*M*
Red-billed Gull	O		H	H O D
White-fronted Tern	O M	H* D*	H* D*	H*O D*M
North Island Kaka			H	
Parakeet sp.				H O
Shining Cuckoo				H O
Long-tailed Cuckoo				O
Morepork	O			H O
Kingfisher	O	O	O	H+O*D M
Kookaburra				H
Skyllark	O	H	D	O
Welcome Swallow				H*O*D M*
Pipit	O			
Hedgesparrow		O	H O D M	H*O+D M
Grey Warbler	O	H O*	H O D M	H*O+D M
Fantail	O	H O	H O M	H*O*
Song Thrush			M?	H*O*
Blackbird	O M	H*O*D	H O D*M	H*O*D M
Silveryeye	O M	H O	H O M	H*O+D M
Tui			H	H O M
Yellowhammer		O		O M
Chaffinch	O M	H O	H D M	H*O+D M
Greenfinch				H*O*
Goldfinch		H O	H	H*O+D M
House Sparrow				O
Starling	O M	O	H O D M	H*O+D M
Myna			H	H O
Magpie				H O
<u>B. Birds seen only at sea near the Noises Islands</u>				
Northern Giant Petrel				S
Flesh-footed Shearwater				S
Buller's Shearwater			S	S
Fluttering Shearwater			S	S
Little Shearwater				S
Australasian Gannet	S	S		S
Southern Great Skua			S	
Arctic Skua	S	S		S
Caspian Tern	S			S
Total species	24	20	28	48

H = Motuoropapa (including observations from Tern Rock and Ike Island)

O = Otata (including observations from Scott and Sunday Islands)

D = David Rocks

M = Maria

S = At sea near the Noises Islands

* = Breeding

+ = Breeding likely but not confirmed

NORTHERN BLUE PENGUIN *Eudyptula minor*

A conspicuous species observed throughout the year, mostly when moulting or breeding. It was also seen at sea as solitary birds or pairs and occasionally in greater numbers feeding among flocks of White-fronted Terns (*Sterna striata*) and Fluttering Shearwaters (*Puffinus gavia*).

Most penguins nested in burrows, some of which had previously been occupied by breeding Grey-faced Petrels. Other sites used were rock crevices, beneath clumps of *Astelia banksii* or dead fronds from phoenix palms (*Phoenix canariensis*), and beneath the house on Otata. Our earliest record of incubation was 4 October and our latest 2 November. The mean dimensions of seven eggs were 53.7 mm x 41.1 mm and the average weight of five was 46.8 g. The heaviest (56 g) was a single fresh egg, probably the first of the clutch because older eggs with more advanced embryos weighed markedly less, the lightest being 39 g. These measurements are similar to the averages reported by Jones (1978) for Northern Blue Penguins on Tiritiri Island 10.3 km north-west of Motuhoropapa.

Moulting birds or shed feathers were seen by us mainly in January and February, although a moulting adult was found on Motuhoropapa as late as 22 April 1979. One burrow on Otata which held a well-grown petrel chick in mid-December 1980 was occupied by two moulting penguins on 24 January 1981.

The penguins were very vocal between April and August. Monosyllabic "yapping" in waters close inshore was particularly common in April, mainly in the afternoon.

GREY-FACED PETREL *Pterodroma macroptera gouldi*

Common during autumn and winter and often found on the ground or heard at night during April and June. It nests in burrows, usually in small colonies, on Motuhoropapa, Scott, Sunday, Otata and Maria Islands. Incubating petrels were found in August and early September, and chicks were present from mid-September until late December.

The localities and approximate sizes of the colonies on Motuhoropapa and Otata are shown in Figures 2 and 3. We estimated that there were about 75 burrows on Motuhoropapa and 150 on Otata, mostly in colonies of 10-20 burrows. However, the numbers of breeding pairs were much fewer than these totals because repeated inspections revealed that fewer than half of the burrows held active petrel nests. The other burrows were apparently kept open by prospecting petrels and sometimes by penguins. In April 1963, Lois Bishop (unpubl.) and the Selwyn College Biology Club noted the distribution of petrel burrows on Otata. Based on a count of "cleared" burrows, they estimated a breeding population of 200 pairs. However, their map does not show any burrows in the north-east sector of the island where we discovered several colonies (Fig. 2).

In April 1938 members of the Auckland University Field Club visited Scott and Sunday Islands and found dead petrels at the entrances to burrows.

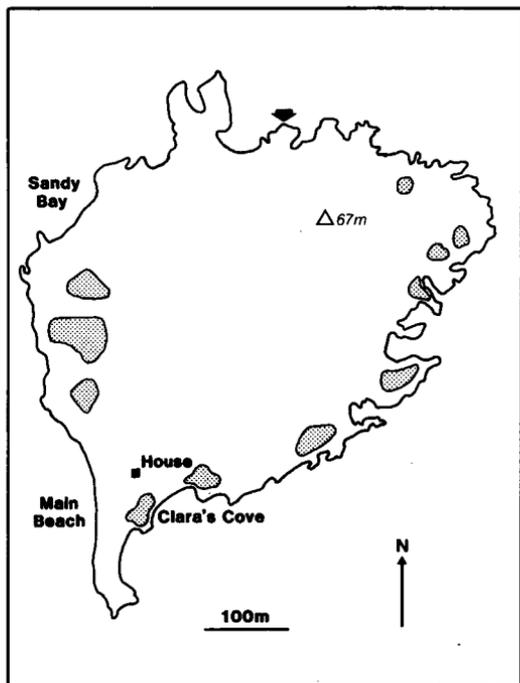


FIGURE 2 — Localities on Otata Island and the distribution of Grey-faced Petrel burrows. Arrow indicates the nesting ledges used by Spotted Shags (see text)

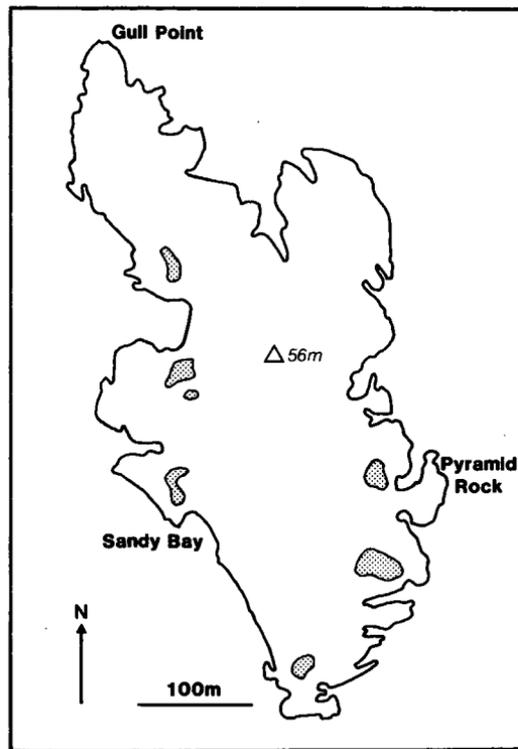


FIGURE 3 — Localities on Motuhoropapa Island and the distribution of Grey-faced Petrel burrows

According to the author of the Field Club notes the carcasses "lay rotting, with the appearance of having been killed by a mammalian predator." Stoats (*Mustela erminea*) were temporarily present on Otata in the 1950s (B. P. Neureuter, pers. comm.), but there is no evidence that these mustelids or other carnivores inhabited the Noises at an earlier date.

NORTHERN GIANT PETREL *Macronectes halli*

A beached carcass was found on Otata in December 1981, and a bird was seen 200 m north of Tern Rock on 19 August 1983.

FLESH-FOOTED SHEARWATER *Puffinus carneipes*

Seen from February to April, occasionally in the company of Buller's Shearwaters, feeding over schools of kahawai (*Arripis trutta*). In mid-February 1983 large numbers were sighted passing to the north of Motuhoropapa.

BULLER'S SHEARWATER *Puffinus bulleri*

Seen mainly in mid to late summer, but one observed in June 1980. Usually solitary, but twice observed feeding over schools of fish with White-fronted Terns and Fluttering Shearwaters. Between 29 January and 3 February 1982 and also in February 1983, large numbers were seen most mornings flying eastward in a constant stream to the north of Ike.

FLUTTERING SHEARWATER *Puffinus gavia*

Very common during autumn and winter, often in flocks of several hundred in June and August. They were usually seen feeding among kahawai shoals, often with White-fronted Terns, Red-billed Gulls (*Larus novaehollandiae*) and Australasian Gannets (*Sula serrator*).

Fluttering Shearwaters begin returning to their breeding colonies in August (Falla *et al.* 1979), but very few were seen near the Noises between September and April. Breeding has not been confirmed at these islands, although Skegg (unpubl.) observed birds landing on Maria in November 1962. He noted "at least 20 birds coming in, possibly many more. Best area appears to be just around from the landing". A sketch in his notes shows an area on the south side of the island east of the track leading to the navigation light.

LITTLE SHEARWATER *Puffinus assimilis*

Heard calling over Maria Island on 27 April 1979.

WHITE-FACED STORM PETREL *Pelagodroma marina*

Not recorded at sea by us, but found breeding in variable numbers on Maria Island, where in the past there was a large colony (Falla 1978; C. A. Fleming, pers. comm.).

In northern New Zealand, White-faced Storm Petrels begin laying in the second half of October (Falla *et al.* 1979). We inspected about 30 burrows on Maria on 25 October 1979, but all were empty except one containing a lone adult. Sixty-five burrows checked on 16 December 1980 yielded only

two small downy chicks, an additional moribund chick and a desiccated chick carcass. Most of these burrows had been cleaned out and gave off the typical petrel odour, but there appeared to have been very little successful breeding. About half the 70 burrows inspected on 18 November 1981 contained adults incubating a single egg. Three weeks later on 11 December a third of 37 burrows held either a chick or an incubating adult.

Periodic visits to the David Rocks during 1977-1983 failed to produce any evidence of breeding there. The only storm petrel records for Motuoropapa are an old skull found on Pyramid Rock in June 1980 and an adult caught at a light on 17 November 1981.

Falla (1978) visited Maria Island many times between 1918 and 1938. On 3 March 1934 he found that two-thirds of the burrows were empty and the youngest chick was within a week of fledging (Falla 1934). According to Falla's field notes (P. D. G. Skegg, pers. comm.), on 31 December 1934 chicks were 8-10 days old with feather tracts just showing under the down. The colony suffered a setback in the summer of 1959-60 when recently introduced Norway rats killed several hundred storm petrels (J. Brown, *in litt.*). A Junior Royal Forest and Bird Protection Society party from Waiheke Island led by A. McDonald laid warfarin rat poison in January 1960, and again later in the year (Burns 1960). D. V. Merton from the New Zealand Wildlife Service continued the poisoning and by 1964 had eliminated the rats. During this period the storm petrels continued breeding in large numbers. Merton (unpubl. 1960) reported that about 50% of burrows held incubating adults in November 1960. In the same month in 1962 Skegg (unpubl. 1963) found large numbers breeding and banded over 60 in three hours one evening. Burrows had been "cleaned and lined" in late September 1963 (Merton unpubl. 1963), and on 5 December 1964 Merton estimated that more than 2000 birds were incubating (OSNZ Nest Records Scheme). The storm petrels on Maria suffer occasional predation from Southern Black-backed Gulls (*Larus dominicanus*) and Australasian Harriers (*Circus approximans*). In November 1962 Skegg (unpubl. 1963) found 33 birds killed by gulls, and in January 1979 C. R. Veitch (pers. comm.) found 29 carcasses from predation by gulls or harriers.

Incubating storm petrels were found on the David Rocks in December 1946 and November 1947 (Sibson 1948a, 1949, unpubl.). In November 1962, Skegg (unpubl. 1963) found three cleaned-out burrows and dead storm petrels apparently eaten by rats. Sibson (unpubl.) also landed on Ike Island in December 1946 and was able to locate the burrows, then old and deserted, where storm petrels had previously been found breeding by Mr M. Johnson.

NORTHERN DIVING PETREL *Pelecanoides urinatrix*

A dead, recently fledged juvenile was found floating between Motuoropapa and Ike on 19 December 1978, and a skull fragment was found on top of Orarapa on 23 October 1980. The only evidence of breeding was a large downy chick found dead at a burrow entrance on Maria on 18 November 1981. Other burrows nearby were searched without success on 11 December 1981, by which time most chicks would have left (Thoresen 1969). McDonald

(pers. comm.) recalls diving petrels occasionally landing on Maria during the mid-1950s. In November 1962 Skegg (unpubl. 1963) found eight carcasses on the southernmost David Rock, the skulls of which appeared to have been eaten by rats.

AUSTRALASIAN GANNET *Sula serrator*

Seen frequently at sea throughout the year. Gannets do not breed at the Noises, the nearest colony being on Horuhoru Rock 18 km to the east.

BLACK SHAG *Phalacrocorax carbo*

Seen in autumn and winter 1979 at roost trees on Otata and Motuhoropapa. They are probably only occasional visitors to the Noises.

PIED SHAG *P. varius*

Common on the reefs around Motuhoropapa, Otata and the David Rocks. There is a breeding colony in pohutukawa trees above Clara's Cove at the south-eastern corner of Otata. A roost in pohutukawa at the north end of Sandy Bay on Motuhoropapa is used intermittently.

Breeding at the Otata colony was recorded in 1962 and 1963 by Skegg (unpubl.), Bishop (unpubl.) and Merton (unpubl. 1963), and it continued until about 1970 when many of the birds were illegally shot (B. P. Neureuter, pers. comm.). Our counts of Pied Shags roosting at Clara's Cove increased steadily and breeding had resumed by September 1981. Ten nests and 24 chicks of various sizes were counted on 12 December 1981. Since 1981 the maximum number of adults counted at the colony has been 35, although not all were breeding. The number of nests has not increased.

LITTLE SHAG *P. melanoleucos*

Usually single birds were seen perched on reefs or small rock stacks around Motuhoropapa and Otata, although up to 10 birds roosted at high tide on the stack at the southern end of Scott Island and in pohutukawa north-east of the Pied Shag colony at Clara's Cove. This species does not breed at the Noises Islands.

SPOTTED SHAG *Stictocorax punctatus*

Seen intermittently by us on the Noises and at sea nearby, but seen more often and in greater numbers by earlier observers. We saw 11 birds roosting on the separated David Rock on 18 February 1978. A few days later, 30-40 were roosting on the reefs at Sandy Bay, Motuhoropapa, and 70-100 flew past heading southwards. In August 1982 about 50 were roosting at high tide on the northern end of Ike Island.

Turbott (1956) reviewed the breeding of Spotted Shags at the Noises between 1920 and 1956, and Millener (1970) reported observations from the 1970 breeding season. Additional information covering the period 1923-1962 has since come to light from sources listed in Table 1, and the following account summarises the known breeding history of this shag at the Noises.

According to Falla (1932), there were Spotted Shag colonies throughout much of the Hauraki Gulf in 1910. Shooting by boating parties dramatically reduced the number of colonies (Buddle 1951) so that, by 1931, only one remained in the western part of the gulf "in a narrow tunnel that pierces a small islet" (Falla 1932). This is an accurate description of the cave in the separated David Rock, where subsequent observers regularly found nests. At least 50 birds were nesting in this cave on 31 August 1931 (Falla, unpubl.), and an Auckland University Field Club party found nests there in May 1933. By the late 1940s, numbers at the David Rocks had increased to apparent saturation point (Cox 1946, Sibson 1948b) and they remained at this level well into the 1950s. A maximum of 200 birds (juveniles and adults) was recorded by Turbott (1956) on 3 March 1956. About a year later Gillham (1960a) saw 60-70 birds roosting at the cave, but numbers seem to have dwindled thereafter. In November 1962 Skegg (unpubl.) saw only 15 birds. Sibson (unpubl.) found about 20 in March 1963, and it may be significant that he also found spent cartridge cases. Merton (unpubl. 1963) noted six nests in September 1963, Millener (1970) counted 25 birds on 22 March 1970 and seven occupied nests inside the cave on 12 April 1970, and Gaunt (*in litt.*) found chicks on 11 December 1971. Since then there have been no records of breeding at the David Rocks.

The colony on the northern cliffs of Otata Island was reported by Falla (1932) as having 100 birds in 1923, but it had disappeared by 1931. A breeding attempt in 1934 was apparently thwarted by shooting (Falla, *in* Turbott 1956). Breeding on Otata was not observed again until December 1946 (Sibson 1948b). Records from 1946 onwards show that this colony thrived until at least 1957 (Gillham 1960a), although it never became as large as the one on the David Rocks. Shags were absent in November 1962 (Skegg, unpubl.), and Merton (unpubl. 1963) did not report any in September 1963. Millener (1970) found 100 birds and 24 nests in March 1970, but the nests had gone on 3 May 1970 (J. Gaunt, pers. comm). The shags did not breed between 1977 and 1982, and we did not see any roosting at the old colony site. However, three nests were present on 28 April 1983, one nest containing three eggs and the other two nests being in the course of construction. About 50 birds were roosting on the nesting ledge and nearby reefs. No trace of the nests or roosting shags remained when we next inspected the site in August 1983.

Similar variation in the numbers and breeding of Spotted Shags has also been noted in the past at other colonies in the region (e.g. see Millener 1970). Illegal shooting and other disturbances have caused some of the changes, and the increasingly heavy boating and fishing pressure on Hauraki Gulf waters may also be responsible. More information about distribution and breeding performance would help clarify the status of the Gulf population and the significance of fluctuations at particular colonies.

WHITE-FACED HERON *Ardea novaehollandiae*

One bird was on the reefs at Sandy Bay, Motuhoropapa, at low tide on 27 April 1982.

REEF HERON *Egretta sacra*

Single birds were occasionally seen around the reefs and beaches of Otata and Motuhoropapa, and two were seen on the rock platform of Orarapa in February 1979. No evidence of breeding.

GREY DUCK *Anas superciliosa*

First recorded on 28 August 1979, when a pair flew southwards between Ike Islet and Motuhoropapa. On 23 September 1979, two birds took off from the edge of a large pool of rainwater on Ike; no nest was found.

AUSTRALASIAN HARRIER *Circus approximans*

Seen and heard throughout the year. Most observations were of 1-4 birds circling Motuhoropapa or Otata and occasionally the intervening islets. Harriers were also observed on three occasions flying over the sea up to 1 km from the nearest island. Dark juveniles were seen in January and February.

A. McDonald (pers. comm.) reported that a chick was raised on Maria in the mid to late 1950s. Breeding was not recorded again until this study, when we found three nests. The first (8 December 1977) was built among dense shrubs on Motuhoropapa. It was supported by a 50 cm pedestal of dead bracken fronds and stems and contained three downy chicks, the smallest of which disappeared within four days. The second nest (17 December 1980) was sited on the ground among clumps of *Gahnia lacera* on Otata. It held three chicks and a cold egg, and the smallest chick disappeared within 24 hours. The third nest (18 November 1981), also on Otata, was similar in siting and construction to the previous one. It initially contained four eggs and when checked on 12 December had three small chicks and a cold egg.

Table 3 lists the foods identified in the 26 Harrier pellets, 23 of which were collected from Motuhoropapa, two from Maria (in association with several White-faced Storm Petrel carcasses) and one from Orarapa. Eighteen pellets contained more than 90% feathers, and bird remains were present in all but two, which were 99% wool. Passerine birds, mainly finches and Blackbirds (*Turdus merula*), were the most frequent prey. The rails were probably Pukeko (*Porphyrrio porphyrio*) because remains of adults and juveniles were found at plucking stations on Motuhoropapa and Otata in January 1982. Pukeko are not at the Noises but occur on Rakino and Motutapu Islands, 2.3 km and 4.5 km respectively to the south-west. Petrel remains were from White-faced Storm Petrels; a leg was also found at a plucking site of Otata in December 1981. Fragments of tern feathers were found in two pellets, and in January 1978 a White-fronted Tern wing was collected from the Harrier nest on Motuhoropapa. Larger bird prey such as adult Pukeko and gannets are probably able to defend themselves against Harriers and are therefore likely to be taken only as carrion. Mammalian remains were found in 14 pellets, generally in small amounts. Norway rats were the only mammals on the Noises Islands and were present in low numbers. The other mammalian prey must have been captured on neighbouring islands. Rats, house mice (*Mus musculus*) and sheep (*Ovis aries*) occur on Rakino and Motutapu, and possums (*Trichosurus vulpecula*)

on Motutapu. The repeated presence of wool, mice and Pukeko in the diet demonstrates that the Harriers hunted for food over a much larger area than the Noises Islands.

BROWN QUAIL *Synoicus ypsilophorus*

Common on Otata in the 1920s and 1930s, and last recorded about 1960 (B.P. Neureuter, pers. comm.).

SOUTH ISLAND PIED OYSTERCATCHER *Haematopus ostralegus*

Present on Sunday Island in September 1979 and on Otata in June 1980.

VARIABLE OYSTERCATCHER *H. unicolor*

One seen in August 1979 on Scott Island. Two were foraging along the shoreline of Sunday Island in September 1981, and a pair was seen periodically after that on Otata and Scott.

SOUTHERN GREAT SKUA *Stercorarius skua lonnbergi*

One seen chasing White-fronted Terns south of Otata on 21 April 1963 (L.J. Bishop, unpubl.).

ARCTIC SKUA *S. parasiticus*

Regularly encountered at sea around the Noises between November and April harassing White-fronted Terns and once a juvenile Black-backed Gull on the fringes of feeding flocks. Both the light and the intermediate colour phases of plumage have been recorded.

TABLE 3 — Prey identified in 26 Harrier pellets collected on the Noises Islands

Prey	Occurrence in pellets	
	n	%
Bird	24	92.3
Petrel	4	15.3
Rail	2	7.7
Gannet	1	3.8
Tern	2	7.7
Passerine	18	69.2
Mammal	12	46.1
Possum	1	3.8
Rat	3	11.5
Mouse	2	7.7
Sheep (wool)	4	15.3
Unidentified	4	15.3
Insect	16	61.5
Beetle	10	38.5
Unidentified	8	31.0

SOUTHERN BLACK-BACKED GULL *Larus dominicanus*

Present throughout the year and common from June to January. It breeds on all islands and most vegetated rock stacks. Small colonies occur at Gull Point on the northern tip of Motuhoropapa and on the northern part of Ike.

Gulls first occupied breeding sites in the middle of September and began nest building by mid-October. Nests were composed mostly of grass and pieces of ice plant (*Disphyma australe*). Clutch size varied from one to three eggs and was typically two. Mean dimensions of 13 eggs were 68.8 mm x 46.3 mm, with a mean weight of 75.0 g. In 1957 Gillham (1965) noted Black-backed Gulls nesting at Gull Point, and on Ike with White-fronted Terns. Skegg (unpubl.) counted nine nests at Gull Point and 10 on Maria in November 1962.

RED-BILLED GULL *L. novaehollandiae*

Common between April and September, but not known to breed at the Noises Islands. The gulls were most abundant in winter when groups of up to 30, mostly adults, were observed feeding on schools of fish with Fluttering Shearwaters and White-fronted Terns. The largest flock encountered was of about 500 birds feeding at the top of the tide off the southern end of Ike on 4 August 1981.

CASPIAN TERN *Hydroprogne caspia*

One seen near the David Rocks and two at the southern tip of Otata in February 1983.

WHITE-FRONTED TERN *Sterna striata*

Seen in nearly every month of the year during our study, the largest numbers occurring from April until August.

White-fronted Terns bred at the Noises in the past, but they are notoriously fickle in their choice of colony sites and we did not find them breeding until 1981. On 12 December, 133 nests were present on the southern face of Ike Island and 20 on Tern Rock. Two days later we counted about 30 nests on the David Rocks and found an additional 60 fresh nests on Ike and 10 on Tern Rock. On 30 January 1982, two large chicks and a large area of guano-covered rock on the northern part of Ike indicated that more birds had bred there. The colonies on southern Ike and Tern Rock were no longer present, and we were unable to determine if breeding had been successful there.

Two nests had clutches of two eggs and the rest had single eggs. Mean measurements of 10 eggs were 46.3 mm x 32.2 mm, with a mean weight of 25.8 g. These measurements are similar to those reported by Mills & Shaw (1980) for White-fronted Terns on the east coast of the South Island.

At least 150 pairs were breeding on Ike when Gillham (1960b) visited the Noises late in 1957, and a larger colony was present on the David Rocks.

In November 1962 Skegg (unpubl.) found 12 pairs breeding on the central islet of the David Rocks and 20-25 pairs preparing to breed on Tern Rock. According to B. P. Neureuter (pers. comm.), terns bred on Ike in 1975 or 1976.

NORTH ISLAND KAKA *Nestor meridionalis*

Skegg (unpubl.) observed a Kaka "ripping bark off pohutukawa" on Motuhoropapa in November 1962. This is a most unexpected record because suitable forest is not present and the nearest Kaka are on the Coromandel Peninsula, 38 km to the north-east.

PARAKEET *Cyanoramphus* sp.

The chattering of parakeets was heard twice on Motuhoropapa early on the afternoon of 24 February 1979. About 10 minutes later they were heard and fleetingly seen flying rapidly over Otata. The nearest population of Red-crowned Parakeets (*C. novaeseelandiae*) is on Tiritiri Island, and the nearest Yellow-crowned Parakeets (*C. auriceps*) are on Little Barrier Island, 47 km to the north.

SHINING CUCKOO *Chrysococcyx lucidus*

Heard in October 1978 on Scott, Sunday, Motuhoropapa and Otata Islands, and again on Otata in September and October 1979. One was seen briefly at the north end of Motuhoropapa in February 1982.

LONG-TAILED CUCKOO *Eudynamys taitensis*

The characteristic call of this bird was heard on Otata on 24 February 1980, and the bird was later seen perched in a small tree above Sandy Bay.

MOREPORK *Ninox novaeseelandiae*

One was mist-netted during the day in April 1978 on Motuhoropapa, and another was heard and seen on Otata in August 1979. In April 1980, one was found roosting near the ground in forest above Sandy Bay on Motuhoropapa. The bird was unperturbed by mobbing from Silvereyes, Fantails and a Blackbird.

KINGFISHER *Halcyon sancta*

Recorded throughout the year on Motuhoropapa and Otata and less frequently on the other islands. Usually single birds were seen, often revealing their presence by their characteristic call. A pair bred successfully in January 1982 in a traditional nest-hole on Otata (B.P. Neureuter, pers. comm.).

KOOKABURRA *Dacelo novaeguineae*

One observed on 26 October 1979 in a pohutukawa above Pyramid Rock on Motuhoropapa. Kookaburras occur on the western shores of the Hauraki Gulf between Cape Rodney and Whangaparoa Peninsula and are occasionally reported on Little Barrier Island (Falla *et al.* 1979).

SKYLARK *Alauda arvensis*

One seen hovering over a grassy slope north of the Otata trig in September 1979 may have been blown from grassland on Rakino by a strong south-westerly wind the previous day. The Auckland University Field Club reported Skylarks on Otata in May 1933.

WELCOME SWALLOW *Hirundo tahitica neoxena*

Observed in most months except June and very common from August to February. It was common to see swallows hawking above the canopy or quartering the slopes and coastal coves on all islands in the group. Nests were found on Otata in November 1977, on Maria in December 1978, and on Motuhoropapa in December 1981 and February 1983. All were in inaccessible sites, usually sea caves.

NEW ZEALAND PIPIT *Anthus novaeseelandiae*

Recorded by the Auckland University Field Club on Otata on 23 June 1934.

HEDGESPARROW *Prunella modularis*

Common on all islands except Scott, where it is probably present. Breeding has been recorded for Motuhoropapa and is likely to occur throughout the group.

GREY WARBLER *Gerygone igata*

Seen throughout the year on all islands and islets except Orarapa. Grey Warblers definitely breed on Motuhoropapa and probably do so throughout the group. Thirteen were colour-banded on Motuhoropapa by Moynihan & Imboden (in prep.) between December 1977 and November 1978. Their censuses and sightings of banded Grey Warblers showed that 13 or 14 territories were on the island with boundaries which altered little from year to year. Juvenile recruitment was very low and residents survived for several years. One banded as a juvenile and two banded as adults were at least four and a half years old when last sighted.

NORTH ISLAND FANTAIL *Rhipidura fuliginosa placabilis*

Very conspicuous at all times of the year on Motuhoropapa and Otata; less common elsewhere and not recorded from Orarapa or the David Rocks. Fantails breed on both Motuhoropapa and Otata.

Fantails used every kind of habitat from rock platforms at low tide to the forest canopy. They were regularly seen hawking insects above open slopes, rocky coves and reefs, and open water. On 16 June 1980 at least 15 birds were hawking above a sunny slope on Motuhoropapa. They were in varying stages of moult, including one with no tail feathers at all.

Fantails are naturally curious and highly mobile, and it was easy to get the impression that they were abundant. However, only 17 were banded by Moynihan & Imboden (in prep.) between December 1977 and November

1978, compared with 42 Blackbirds, 80 Silvereyes and 13 Grey Warblers during the same period. Nevertheless, Fantails accounted for about half of all sightings of colour-banded birds. There were only three Fantail territories on Motuhoropapa, and these appeared to be held by the same adults in successive years. An adult normally resident in the central and eastern parts of the island was seen on Ike Island in June 1981 after crossing 150 m of open water. When next sighted the bird had returned to its previous territory. Three banded birds were known to be at least three and a half years old when last seen.

SONG THRUSH *Turdus philomelos*

Heard often and nests found on both Motuhoropapa and Otata. Their presence was usually revealed by song or a thin high-pitched *seep* emitted on flight. Song was heard in winter and spring. There was no sign of thrushes on the other islands, except for a rat-gnawed egg found on Scott in October 1978.

Houpara fruit and remains of terrestrial snails, cicadas and flies were found in the gizzards of four thrushes caught in rat traps on Motuhoropapa and Otata (Table 4).

TABLE 4 — Foods identified in the gizzards of Blackbirds (n = 13) and Song Thrushes (n = 4) from the Noises Islands

Food	Occurrence in gizzards	
	Blackbird	Thrush
<u>Fruit and seeds</u>	13	2
<i>Pseudopanax lessonii</i>	12	2
<i>Leucopogon fasciculatus</i>	3	-
<i>Tetragonia trigyna</i>	1	-
<i>Pimelea prostrata</i>	1	-
<i>Melicope ternata</i>	1	-
<i>Pseudopanax arboreum</i>	1	-
<i>Coprosma macrocarpa</i>	1	-
<i>Myoporum laetum</i>	1	-
<u>Molluscs</u>	5	3
<i>Laoma poecilosticta</i>	2	-
<i>Laoma glabriuscula</i>	1	1
<i>Oxychillus cellerius</i>	1	-
<i>Therasia</i> sp.	1	-
<i>Risellopsis varius</i>	1	-
<i>Estea zosterophila</i>	1	-
<u>Insects</u>	13	4
Coleoptera	8	1
Hymenoptera	6	1
Hemiptera	5	2
Diptera	3	3
Lepidoptera	1	1
Dermaptera	1	-
<u>Other Invertebrates</u>	9	3
Arachnida	6	1
Crustacea	3	-
Myriapoda	2	-
Annelida	1	-

BLACKBIRD *Turdus merula*

Very common throughout the Noises Islands. Nests were found and juveniles seen on Otata and Motuhoropapa. Blackbirds were very shy, making sightings difficult. However, other signs of their presence such as song, alarm calls, diggings and captures in rat traps and mist-nets clearly showed that Blackbirds were abundant. The longest period of residence was five and a half years for a male originally banded as a juvenile.

Many Blackbirds were accidentally killed in traps set for Norway rats. Gizzards were collected from 13 birds, and food remains identified in them are listed in Table 4. Houpara berries, available in varying stages of ripeness from February to October, were the most commonly taken fruit. They were in 12 gizzards, one of which contained 14 berries. Mingimingi (*Leucopogon fasciculatus*) was the only other fruit or seed found in more than one gizzard.

Invertebrate remains, especially insects, were in all the gizzards. Beetles (order Coleoptera) were the most frequent prey, being present in eight gizzards. Six gizzards contained ants (order Hymenoptera), of which two species, *Amblyopone australis* and *Mesoponera castanea*, could be identified. Hemipterans, mostly cicadas *Amphisalta* sp., and small terrestrial snails were each present in five gizzards. Blackbirds were occasionally seen foraging on the shoreline at low tide. One gizzard from Otata contained the marine snails *Risellopsis varia* and *Estea zosterophila* and a barnacle *Chamaesipho* sp.

SILVEREYE *Zosterops lateralis*

Probably the most abundant forest bird on the Noises group, being present everywhere except Orarapa, it almost certainly breeds on all the main islands. We often encountered foraging Silvereyes in small noisy flocks, and they were observed feeding on houpara and karamu fruit and visiting the flowers of flax (*Phormium tenax*).

TUI *Prosthemadera novaeseelandiae*

An irregular visitor, usually in small numbers except between April and August.

Between April 1978 and June 1980 eight colour-banded birds from Tiritiri Island (10.3 km north-west) were seen on Motuhoropapa, four on Otata and two on Maria. Only one was seen more than once — on Motuhoropapa on 16 June 1980 and on Otata three days later. Most had been banded between February 1977 and January 1979 (M. J. Douglas, pers. comm.), except for an adult seen in June 1980 and banded in November 1974. Three birds had been banded as juveniles but none crossed to the Noises in their natal year.

Tuis were most often seen feeding among kohekohe trees, either on the flowers or among the fruit clusters. Green and ripe houpara berries and occasionally those of five-finger (*Pseudopanax arborea*) were also eaten, and we saw them visiting flowers of karo and whau (*Entelea arborescens*).

In November 1962 Skegg (pers. comm.) recorded in field notes for Motuhoropapa "bellbird: quite a number present". However, he only heard the birds singing and now considers that he misidentified Tui song.

YELLOWHAMMER *Emberiza citrinella*

Present on Maria in August 1977. An adult male was seen on the west side of Otata in December 1981 and another was heard singing at sunset above Sandy Bay, Otata, in late February 1983.

CHAFFINCH *Fringilla coelebs*

Common throughout the Noises and recorded on all our visits. It is known to breed on at least Motuhoropapa, where a nest with young chicks was found in October 1978. Although seen and heard in most habitat types, Chaffinches preferred vegetation dominated by pohutukawa. A male trapped on Motuhoropapa in February 1983 had been banded there as an adult in October 1978.

GREENFINCH *Carduelis chloris*

Two males and a female were mist-netted on Motuhoropapa in June and August 1978, and an adult male was seen with a juvenile on Motuhoropapa in February 1982.

GOLDFINCH *C. carduelis*

Common throughout spring and summer and observed on every island. We found no proof of breeding, but the agitated behaviour of a pair on Otata in October 1979 suggested a nest was nearby. The presence of singing males between October and December also indicated that breeding was likely.

Goldfinches were mainly seen in pairs or small noisy flocks. They often fed in open sites covered with sow thistle (*Sonchus oleraceus*), groundsel (*Senecio lautus*) or ice-plant.

HOUSE SPARROW *Passer domesticus*

One heard chirping near the house on Otata in October 1979. A female was in the same area on 17-20 February 1983.

STARLING *Sturnus vulgaris*

Frequently seen in small numbers on all islands and islets. Breeding was confirmed only on Motuhoropapa, where single nests in rock holes were found in November 1981 and February 1983. Flocks were occasionally seen, including one of 10 and another of 40 on Maria in February 1979 and 1983 respectively and one of 50+ high over Otata in June 1980.

Starlings preferred cliff tops, rocky outcrops and the smaller islands such as Orarapa, the David Rocks and Maria. Starlings from Waiheke Island and possibly further afield roosted on Maria during 1918-1938 (Falla 1978), but we found no evidence that this roost still existed.

MYNA *Acridotheres tristis*

Mynas visited only the larger islands and nearby islets, mainly in winter. They were never seen on Orarapa, the David Rocks or Maria. Pairs or small

groups used a variety of habitats, including beaches, cliffs and the forest canopy. The Myna is not known to breed at the Noises Islands.

MAGPIE *Gymnorhina tibicen*

One was seen near the summit of Otata in October 1979 and another at Gull Point on Motuhoropapa in August 1982.

DISCUSSION

Of the 52 bird species listed, 37 had been recorded by 1964. Most of the 15 species added since 1977 can be attributed to our being regularly on the islands and so being able to observe infrequent vagrants. However, two species, the White-faced Heron and the Welcome Swallow, were uncommon and absent respectively in the Auckland region during the three earlier periods of observation. White-faced Herons had only just become established by 1960 (Carroll 1970), and Welcome Swallows were not reported from the district until the early 1960s (Edgar 1966). Both are now common, the swallow also being well established on the Noises. A similar sequence of events has occurred at the Cavalli Islands off the north-east coast of Northland. Millener (1980) first saw White-faced Herons there in 1980 and confirmed Crockett's report of a dramatic increase in Welcome Swallows from the single pair seen in 1969 (in Millener 1980).

Four species seen at the Noises before 1964 have not been recorded since: the North Island Kaka and Southern Great Skua are only rare vagrants at the islands, and the Brown Quail and pipit no longer inhabit Otata. Quail favour the grassy margins of saltmarsh and scrub, and pipits prefer rough, open country (Falla *et al.* 1979), all of which Otata does not have. More favourable habitats existed after the fire in the late 1920s, but vegetational succession has now made the island largely unsuitable for these birds. The disappearance of quail in about 1960 may also have been associated with the introduction of Norway rats a few years earlier. Vegetational changes may be responsible for the disappearance of both these birds from Tawhiti Rahi in the Poor Knights Islands (McCallum 1981) and for the decline of pipits on the Cavalli Islands (Millener 1980).

Twenty-one species breed at the Noises, including eight of the 20 species of seabird and 13 of the 32 species of land bird. The breeding land birds comprise six native species and seven introduced ones. Past visitors to the islands had recorded breeding by only three of the land birds — the Harrier, Grey Warbler and Blackbird. These ornithologists usually spent only a few hours ashore and tended to concentrate on the numbers and breeding status of Spotted Shags and White-faced Storm Petrels.

Grey Warblers, Fantails and Silvereyes are the only native forest birds which breed on the Noises Islands. Such a low number of species would be predicted on island biogeographic grounds, given the small size of the islands and the lack of diversity in species composition, age and structure of the forest. The presence of these species also agrees with recent analyses of the distribution of native forest birds on islands. They are the only species (together with the Morepork) which East & Williams (1984) reported as breeding on islands

less than 20 ha in area, and they are three of the four species which Diamond (1984) characterised as being the most likely colonisers of islands less than 100 ha in area. Grey Warblers, Silvereyes and Fantails readily cross water and also have high population densities, which favour migration and the consequent colonisation of islands (Diamond 1984). As East & Williams (1984) pointed out, they also have versatile habitat requirements, enabling them to survive in simplified habitats on small islands.

Birds were not an important item in the diet of Norway rats on the Noises Islands (Moors, in press). Small amounts of feathers were present in six of the 36 rat stomachs. Feathers in two stomachs belonged to a Little Blue Penguin and a Grey-faced Petrel chick. A partly eaten Grey-faced Petrel chick was found on Motuhoropapa, and rat-bitten eggs were found on four occasions. It was not possible to tell whether the rats had killed the birds or had merely scavenged carrion. Although rats seem to have had no recent effects on bird numbers, they may have had a major impact in the past on White-faced Storm Petrels at the David Rocks. Storm petrels have not re-established there since the eradication of Norway rats in the early 1960s (Merton unpubl. 1963). Imber (1975) has suggested that a petrel colony is endangered when invaded by a species of rat whose adult weight approaches or exceeds that of the petrel. The average weight of New Zealand White-faced Storm Petrels is 47 g (Richdale 1965), compared with a mean of 258 g for adult Norway rats from the Noises (Moors, in press). This is a massive difference, and according to Imber's rule of thumb, the storm petrels on the David Rocks would have been at serious risk. Norway rats are known to have preyed on 26 other species of seabird, causing declines in the populations of at least five species breeding on islands (Atkinson 1985).

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SHORT NOTE

Unusual riverbed birds in the Eglinton Valley, Fiordland

We often watch riverbed birds near the junction of Dunton Creek and Eglinton River 37 km north of Te Anau. This site, which is c. 70 ha of shingle flat split by braided channels with Russell lupin (*Lupinus polyphyllus*), mat plants and grasses, is inside Fiordland National Park (R. W. G. Dalgish, pers. comm.). Regular breeding birds are Black-billed Gull (*Larus bulleri*), Banded Dotterel (*Charadrius bicinctus*), South Island Pied Oystercatcher (*Haematopus ostralegus finschi*), Spur-winged Plover (*Vanellus miles novaehollandiae*), Canada Goose (*Branta canadensis*), Skylark (*Alauda arvensis*) and a few Black-fronted Tern (*Sterna albobstriata*). Gull and tern nests are often destroyed by spring floods.

On 3 October 1983, a cool overcast day, we saw a small dark bird flying like a Welcome Swallow (*Hirundo tahitica neoxena*) over the river flat. We watched the bird with binoculars for 53 minutes as it covered a span of 500 m over Dunton Creek, shingle flat and sheep pasture. Our field notes follow: Smaller than the Chaffinches (*Fringilla coelebs*) flying near it. General shape that of a Welcome Swallow but more compact with shorter, pointed wings, which were angled back; tail only slightly forked. Dusky blue on top of head, broad white rump, smudgy throat and upper breast, underparts whitish from upper breast to undertail coverts, dark-tipped tail, tiny dark bill. Flight fast and erratic, combining steep fluttering climbs, large swoops and glides 2-25 m above the ground. Twice the bird came within 5 m of us. Our identification of an Australian Tree Martin (*Hylochelidon nigricans*) has been confirmed by W. J. Cooper and R. R. Sutton (pers. comm.).

On 21 November 1983 we saw a Wrybill (*Anarhynchus frontalis*) feeding on the edge of Dunton Creek and were searching for others when we saw an unusual tern with conspicuous black head and underparts and light airy flight. This White-winged Black Tern (*Chlidonias leucopterus*) was smaller than the Black-fronted Terns that flew nearby. Its head, breast, belly and wing linings were black, its back was dark grey, its upper wing coverts and tail were white, and its bill was darkish. It flew downstream, dipping several times, to the Eglinton River before disappearing across pasture.

There are no previous Fiordland records of White-winged Black Terns, but they have been recorded in inland Southland at Otautau and near Monowai in 1945 (*NZ Bird Notes* 2: 46-47), Mararoa River in 1961 (Heather 1964, *Notornis* 11: 63) and near Lillburn Valley in 1967 and odd records there 1932-1967 (*Notornis* 19: 60, OSNZ Recording Scheme). Australian Tree Martin and Wrybill have not been recorded in Fiordland or inland Southland (OSNZ Recording Scheme; OSNZ Bird Mapping Scheme 1969 — 1979; W. J. Cooper, R. R. Sutton, W. M. Jukes, pers. comm.). Therefore these three species are new records for Fiordland National Park.

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VARIATION WITHIN THE REDPOLLS OF CANTERBURY

By JOHN F. M. FENNELL, PAUL M. SAGAR
and JUNE S. FENNELL

ABSTRACT

The measurements of the Redpoll (*Carduelis flammea*) in Canterbury, New Zealand, were investigated. Variation in plumage colour are compared with study skins and published data for British Redpolls. New Zealand and British Redpolls are shown to differ and it is suggested that differences may be due to 'founder effect' rather than 'hybridisation' between two or more introduced races, as had previously been postulated. The occurrence of light-coloured plumage was more common in males. Females showed a much wider range of poll colour.

INTRODUCTION

The Redpoll species complex has been the subject of debate for many years, and the validity of some species is still in doubt, let alone the races of supposed species (Troy 1985).

The Redpoll in New Zealand was determined by Westerskov (1953) and Niethammer (1971) as *Carduelis flammea cabaret*. However, Stenhouse (1962) showed that the variation within birds at Lincoln deviated from the published characteristics of *C.f. cabaret* and proposed that New Zealand birds were derived partly from another race, probably *C.f. flammea*.

Such a hypothesis may be true, but the true ranges of variation for the various races have not been clearly described.

The fact that the plumage of Redpolls in New Zealand is variable is well known, but little has been done to record this variation. The main purpose of this study was to investigate the measurements and plumages of Redpolls in Canterbury, New Zealand.

METHODS

From February to June 1983, 590 Redpolls were banded at Courtenay, Canterbury (43° 26'S, 172° 09'E). The birds were caught in mist nets while post-breeding flocks were feeding on various seed crops, particularly favoured being rape (*Brassica napus*) and evening primrose (*Oenothera* spp.). Flocks of up to 2000 birds were noted on the latter crop in March and early April.

An additional 237 birds were caught and banded at Spencerville (43° 24'S, 173° 5'E), north of Christchurch, from June to August 1983. These birds were attracted to small seeds and chaff put out as supplementary stock feed. From this mixture the Redpoll preferred small seed of various grasses, clovers, brassicas and weeds.

The birds were aged and sexed by the criteria of Boddy (1981). They were aged by the shape of fresh tail feathers, first-year birds having more
NOTORNIS 32: 245-253 (1985)

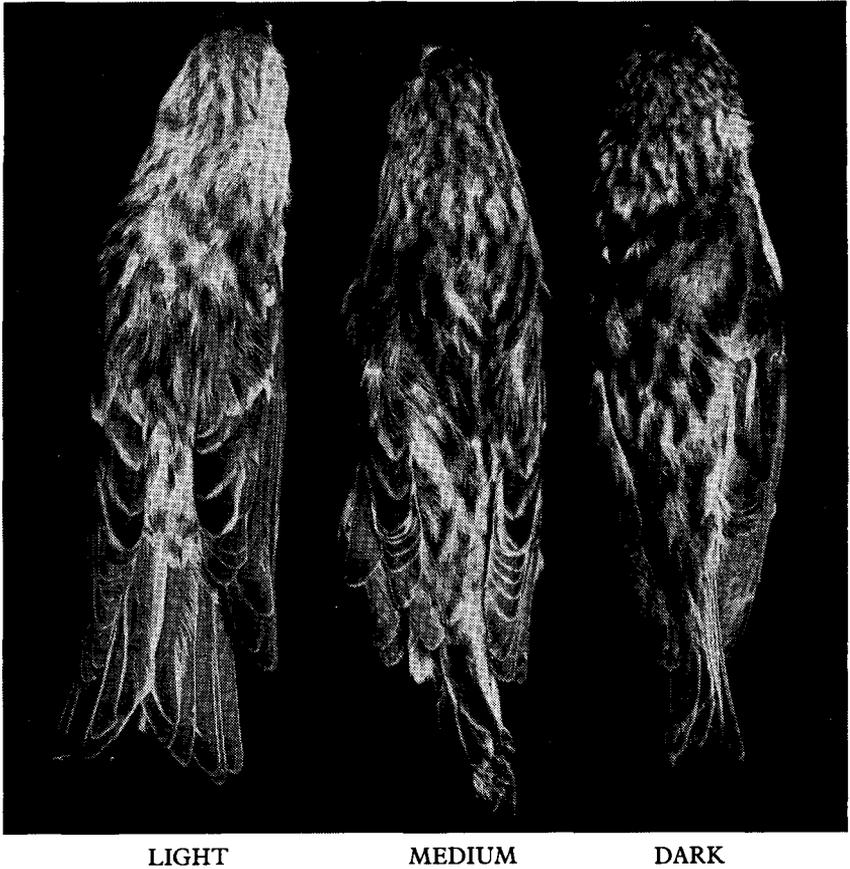


FIGURE 1 — Museum skins of Redpoll from New Zealand showing plumage variation

pointed feather tips than adults. The age of some birds with intermediate tail feathers or with wet or damaged feathers was not determined. Juveniles have a distinctive plumage and lack colour on the crown (poll).

Some Redpolls are hard to sex. During and after the moult, adult birds were sexed according to the amount of red or pink on the breast, cheeks and rump. Birds without pink or red or with only a few pink or red feathers were classed as females. Birds with a general wash of pink or red over the breast were classed as males.

Some birds could not be sexed, and a few may have been incorrectly sexed, but such errors were probably too few to affect the results greatly.

The measurements made were of wing length, tail length, bill length, bill depth, tarsus length, and weight.

Because of the intricate colouring of individual feathers, a colour standards chart was impractical to use in the field. Therefore a simplified plumage description was used. Overall plumage colour of each bird was assessed as being light, medium or dark.

Light birds were generally buff-brown streaked with dark brown and white and often were particularly buff around the neck. Dark birds were grey-brown with very dark brown centres to the back feathers. Plumage colour varied continuously from light through to dark, and we used the three classes mainly to separate the extreme types. Figure 1 shows skins from the National Museum, Wellington, that are examples of these three classes.

For each bird we recorded the amount of white on the rump, the presence of white wingbar, the colour of the poll and the colour of the breast. Rump colour was designated as white, brown or intermediate, disregarding the occurrence of pink or red on males.

Polls of adult and post-juvenile birds were recorded as having no colour or as being bronze, yellow, orange-red, light red, bright red, dark red or purple. Table 1 gives specimens in the National Museum, chosen as standards of these colours for comparison in future studies. Poll size, from front to rear, was measured on a few birds.

TABLE 1 — Redpoll specimens in the National Museum, Wellington, used as colour standards

Poll Colour	Specimen Number	Collected From
No colour	DM9401	Alexandra, Otago
Bronze	DM14708	Gorge Rd, Southland
Yellow	DM13193	Campbell Island
Orange-red	DM13184	Campbell Island
Light red	DM12205	Gorge Rd, Southland
Bright red	DM12196	Gorge Rd, Southland
Dark red	DM14699	Gorge Rd, Southland
Purple	(no specimen available)	

The breast colour of males was recorded as being slightly pink, pink, red or very red. We realise that such subjective assessments do not help anyone attempting comparative work, but the wide variation in shades of pink and red made the colours hard to match precisely to colour standards. The four classes of breast colour we used are not necessarily equal progressions of change from slightly pink to very red but were chosen as being easily determined colour intensities.

After this field study, JFMF examined the study skins of Redpolls of British and European origin in the British Museum (Natural History) at Tring.

RESULTS AND DISCUSSION

Age and sex ratios

Overall, the ratio of males to females was nearly equal (45% male: 55% female). However, the ratio varied widely between catches. In February 41% of the birds caught were female ($n=49$), in March 63% were female ($n=108$) and in May 66% were female ($n=39$). At Spencerville in June one day's catch contained 71% adult males ($n=48$), but in July the sex ratio was equal ($n=86$).

The proportion of young birds also varied considerably. From February to June at Courtenay the monthly percentages of juveniles or first-year birds were 55%, 25%, 6%, 41% and 50%. Such variation in ratios between samples may be due to the flocking of birds of similar age or sex, which is common in finches (Newton 1972).

Most of the birds caught were unbanded, even when catches were made on consecutive days. A low retrap rate between February and March (4.6% of adults and 8.9% of juveniles) indicated that the birds were mostly different ones. The flocks may perhaps have been local birds from exotic plantations on the Canterbury Plains and birds moving down the Waimakariri Valley from the inland high country.

Measurements

Measurements and weights are given in Tables 2 and 3.

The various races of Redpoll vary in size, especially in wing length, and Stenhouse attempted to determine the subspecific status of Redpolls in New Zealand by measurements. He thought that the wing lengths of some New Zealand Redpolls exceeded the range of the British race *C.f. cabaret*, perhaps because some birds of the longer-winged race *C.f. flammea* had also been introduced.

He quoted Witherby (1938) for the wing length range of *C.f. cabaret* as males 67-73 mm and females 63-69 mm. More recent studies, however, show a greater variation in wing length. Evans (1966) recorded that 95% of birds caught in Northumberland had wing lengths ranging male 65-72 mm and female 63-71 mm. Da Prato & Da Prato (1978) reported that males have a range of 69-75 mm and females 64-72 mm in Midlothian. Birds in Nottinghamshire had wing lengths of males 67-74 mm and females 64-73 mm (Boddy 1981). We do not know whether these workers attempted critically to assign their birds as being resident *C.f. cabaret* or immigrant *C.f. flammea*.

With the greatly increased number of Redpolls banded in Britain since 1938, it is more reasonable to accept the ranges quoted by Boddy as being typical of the Redpoll in Britain. Figure 2 shows the wing length distribution of Redpolls in Canterbury. The range is comparable with that of the British birds. Any slight deviation from the British birds, either in range or particularly in frequency distribution, could either be the result of introgression of *C.f. flammea* genes, as proposed by Stenhouse, or the result of a 'founder effect' based upon the genetic contribution of the few birds originally introduced.

TABLE 2 — Measurements (mm) of Redpolls in Canterbury, New Zealand

Measurement		N	Range	Mean	SD
Wing length	Male	198	65.0-74.0	70.0	1.7
	Female	229	63.0-72.0	68.2	1.7
Tail length	Male	46	47.0-55.0	52.1	2.2
	Female	52	47.0-56.0	52.5	2.2
Bill length	Male	66	8.0-10.0	9.1	0.5
	Female	63	8.0-10.4	9.1	0.5
	Juvenile	14	7.5-10.0	8.9	0.6
Bill depth	Male	66	5.5-7.0	6.2	0.3
	Female	63	5.1-7.0	6.0	0.3
Tarsus length	Male	49	13.5-16.5	14.8	0.8
	Female	53	13.1-17.0	15.0	0.8

TABLE 3 — Weights (g) of Redpolls in Canterbury, New Zealand

Age/Sex	Month	N	Range	Mean	SD
Adult male	Feb/Mar	85	10.0-15.0	12.0	0.8
	Jun/Jul	74	11.5-15.5	13.0	0.8
	Aug	47	11.0-15.5	13.3	1.1
Adult female	Feb/Mar	129	10.0-14.0	11.5	0.8
	Jun/Jul	57	10.5-14.5	12.5	0.9
	Aug	51	11.0-13.5	12.4	0.7
Juvenile	Feb/Mar	120	9.5-13.5	11.3	0.9

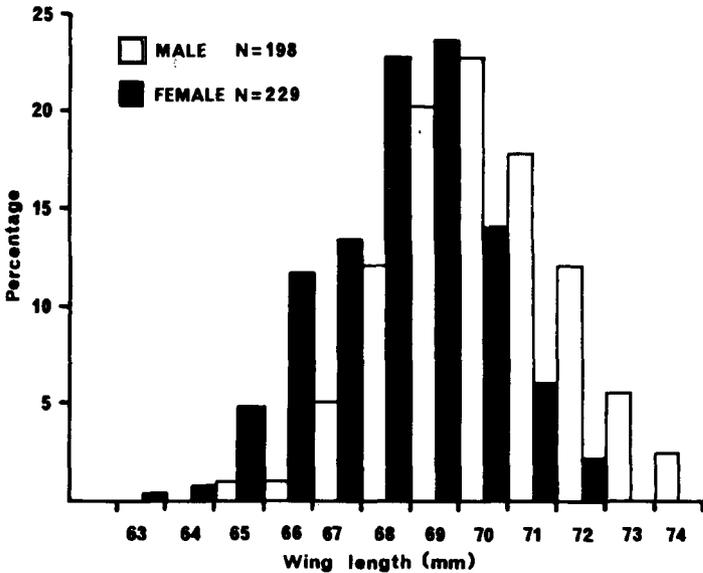


FIGURE 2 — Frequency distribution of wing lengths of Redpolls in Canterbury, New Zealand

TABLE 4 — Plumage variation of 140 male and 186 female Redpolls

Character	Percentage of birds showing character	
	Male	Female
A. Overall plumage colour		
Light	25	13
Medium	41	45
Dark	34	42
B. White wingbar		
Without white wingbar	24	34
	76	66
C. Rump colour		
Mostly white	15	13
Intermediate	54	57
Mostly brown	31	30

Plumage characteristics

Table 4 gives the results from a sample of 326 birds.

More males had light plumage than females. However, light plumage was less frequent overall than dark or medium plumage. Of light males, 71% had white rumps.

Light plumage and the occurrence of a white wingbar were considered to be *C.f. flammea* characteristics (Stenhouse 1962). The present study showed introgression of the various plumage characteristics. White wingbars occurred at a similar frequency in each plumage colour class, but there was a trend for lighter birds to have white rumps and for dark birds to have browner rumps. Some very dark birds, however, had white rumps and wingbars.

The mean wing length of light and dark birds was the same (Table 5). Wing length ranges were also the same for birds with or without white wingbars.

Stenhouse (1962) used data on wing length, plumage colour and occurrence of white wingbar to propose that both *C.f. cabaret* and *C.f. flammea* had been introduced into New Zealand. The present study, with larger samples, confirms and quantifies the frequency of these characteristics.

Examination of the Redpolls in the British Museum revealed that *C.f. cabaret* had a similar range of plumage colouring to New Zealand birds. The collection of British birds contained a higher proportion of dark-plumaged birds, usually without wingbars. However, a few light-coloured birds were similar to those we found in our New Zealand sample.

A museum collection of skins may not be representative of a wild population, and so a comparison of frequencies of plumage types was not attempted.

Poll colour and size

Table 6 gives the range and frequency of poll colour.

The poll size of males ranged from 9.0 to 13.0 mm with a mean of 10.5 mm (n=26). Females generally had smaller polls with a range of 6.5-12.0 mm and a mean of 9.0 mm (n=55). All males had some colour in the poll, but none were recorded with a bronze or yellow poll. Orange-red polls were more frequent in females. Only one bird, a female, had a purple poll. Females therefore had a greater range of poll colour than males.

Poll colour may be due to pigment content or concentration and to feather structure (Troy & Brush 1983). We do not know if pigment content is affected by environmental factors or diet in Redpoll, as has been reported in other finch species (Washington & Harrison 1969).

Breast colour of male Redpolls

The red or pink on the breast of males may depend upon pigment concentration or how far unpigmented feather tips are overlapping and obscuring the colour beneath (Troy & Brush 1983). Feather-tip abrasion can therefore increase the apparent colour intensity. Table 7 shows the change of colouring from March to August.

In March, only 16% of males had red breasts, and this proportion increased through successive months. By August, 78% of birds had red or

TABLE 5 — Relationship between extreme plumage types and wing length (mm) in Redpolls in Canterbury

Sex	Plumage	N	Range	Mean	SD
Male	Light	34	67-74	70.1	1.6
	Dark	41	65-74	70.3	1.9
Female	Light	24	64-71	68.2	1.7
	Dark	79	63-73	68.4	1.8

TABLE 6 — Variation in poll colour of 244 male and 299 female Redpolls in Canterbury

Poll Colour	Percentage of Birds	
	Male	Female
No colour	0.0	0.3
Yellow	0.0	0.7
Bronze	0.0	4.7
Orange-red	4.1	18.1
Light red	4.9	5.7
Bright red	66.8	40.5
Dark red	24.2	29.8
Purple	0.0	0.3

TABLE 7 — Development of breast colour in male Redpolls in Canterbury

Month	Age group	N	Percentage of birds as			
			Slight pink	Pink	Red	Very red
March	Adult	62	55	29	16	0
April	Adult	65	49	17	34	0
May	Adult	9	22	22	56	0
June	Adult	42	7	8	62	23
July	Adult	26	8	11	27	54
August	Adult	31	0	23	23	55
May	First year	4	100	0	0	0
June	First year	11	75	25	0	0
July	First year	13	85	15	0	0
August	First year	11	91	9	0	0

very red breasts. The number of birds with slightly pink breasts decreased from 55% to 0% over the same period.

First-year birds did not develop red breasts but some coloured up to pink from June onwards.

CONCLUSIONS

This study has quantified some of the variation among Redpolls in one district of New Zealand. Some differences do occur between the Redpolls of other New Zealand regions but little is known (Fennell & Sagar 1985). The environment may influence population characteristics but, equally, differences between New Zealand and British Redpolls may be due to the founder effect of a limited genetic input into the New Zealand population. A study of biochemical differences between the two populations might provide further information.

We do not know enough to determine the racial origin of New Zealand Redpolls. In many characteristics, the New Zealand birds deviate little from the British race *C.f. cabaret*, but the frequent occurrence of white wingbars is a major difference. Because few of the birds originally introduced into New Zealand are likely to have survived and bred, a strong genetic founder effect may have occurred in a species with such variable plumage characteristics.

We recommend that Redpolls in New Zealand should not be defined trinomially in terms of the European races.

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SHORT NOTES

Variation between Redpolls in four southern New Zealand localities

INTRODUCTION

A detailed study was made of the measurements and plumage of the Redpoll (*Carduelis flammea*) in Canterbury (Fennell *et. al* 1985). As an extension to this study, JFMF examined the Redpoll skins of the National and Canterbury Museums. These collections included very few specimens from the North Island but good samples from Southland and Campbell Island.

During a visit to the Snares Islands in January 1984, PMS captured a sample of Redpolls for study. These collections allowed us to make a preliminary comparison of variation in the plumage and measurements of birds in Canterbury, Southland, Campbell Island and the Snares Islands.

METHODS

The study material was as follows: 35 skins (20 male and 15 female) from Gorge Road, Southland (46° 29'S, 168° 42'E); 23 skins (12 male and 11 female) from Campbell Island (52° 32'S, 169° 10'E); 24 adults (10 males and 14 females) caught on the Snares Islands (48° 02'S, 166° 36'E); and larger samples caught in Canterbury (43° 26'S, 172° 09'E). The number of Canterbury birds varied for each character, the minimum sample being 46 birds.

Measurements taken were of wing length, tail length, bill length and depth and tarsus length.

Polls were recorded as having no colour or as being bronze, yellow, orange-red, light red, bright red, dark red or purple. The breast colour of males was assessed subjectively.

Colour variation was continuous and we made no attempt to distinguish small differences between individuals.

RESULTS

Table 1 gives the means and ranges of measurements. The measurements of museum skins may be affected by shrinkage, which must be allowed for if compared with the measurements of live birds.

The larger samples from Canterbury are probably representative of the Redpoll in New Zealand. Although the measurements from the three southernmost populations differ, they all fall within the Canterbury ranges.

Table 2 gives the frequency of poll colours in each sample.

Birds from the mainland (Canterbury and Southland) had the widest range of poll colouring. Male birds from both Canterbury and Southland had a similar frequency of colour types, but the females from Southland had a

TABLE 1 — Measurements of Redpolls from four New Zealand localities; range and means (in parentheses). All measurements are in millimetres

Character	Sex	Canterbury	N	Southland†	Snares Is ††	Campbell I †††
Wing length	Male	65-74(70)	198	66-74(70)	66-71(70)	68-71(69)
	Female	63-72(68)	229	63-70(67)	64-71(68)	64-69(67)
Tail length	Male	47-55(52)	46	50-55(53)	49-56(52)	50-56(53)
	Female	47-56(52)	52	49-54(52)	49-54(52)	48-53(51)
Bill length	Male	8-10(9.1)	66	8.1-9.5(8.9)	9-9.8(9.5)	8.5-9.2(8.9)
	Female	8-10.4(9.1)	63	8.0-9.5(8.6)	8.7-10.6(9.7)	8.5-9(8.7)
Bill depth	Male	5.5-7(6.2)	66	5.5-7(6.4)	5.9-6.4(6.2)	5.2-7(6.4)
	Female	5.1-7(6.0)	63	6.1-7(6.2)	4.8-6.2(5.9)	6-6.7(6.4)
Tarsus length	Male	13.5-16.5(14.8)	49	-	14.9-16.2(15)	13.2-15.5(14.5)
	Female	13.1-17.0(15)	53	-	13.1-16.2(15)	13.2-15(14.4)

Samples sizes † 20 male, 15 female
 †† 10 male, 14 female
 ††† 12 male, 11 female

TABLE 2 — Variation in poll colour (percentages)

Poll colour	Canterbury		Southland		Snares Is		Campbell I	
	Male	Female	Male	Female	Male	Female	Male	Female
No Colour	0	1	0	0	0	0	0	0
Yellow	0	1	0	13	0	0	0	18
Bronze	0	5	0	7	0	0	0	36
Orange-red	4	18	10	60	10	64	83	36
Light red	5	6	5	0	0	0	17	10
Bright red	67	40	70	13	90	36	0	0
Dark red	24	30	15	7	0	0	0	0
Purple	0	1	0	0	0	0	0	0
No. birds	244	299	20	15	10	14	12	11

higher proportion of yellow and orange-red polls. However, the sample is small and more work is needed to investigate this apparent difference.

Poll colour varied least on the Snares Islands with only two colour classes noted in either sex.

The majority (83%) of males from Campbell Island had orange-red polls and no birds had bright red polls, which was the most frequent colour in the other localities.

The male Redpolls from Campbell Island had orange or orange-pink breasts, and none of the birds in the museum samples had the pink or red breasts of the birds from other localities.

DISCUSSION

The island birds had less variation in colour than the mainland birds. The birds from Campbell Island were quite distinctive, particularly the males, by their orange breasts. However, it is interesting that Bailey & Sorensen (1962) made no reference to this colouring, even though Sorensen in 1943 had collected many of the museum skins we examined. On a visit to Campbell Island in 1984/85, G. Taylor (pers. comm) confirmed that birds with orange breasts were frequent, but red and pink breasted birds occurred also.

Banding recoveries of Redpolls have not been analysed, and so we do not know whether Redpolls regularly move long distances. We have assumed that the southern islands were originally colonised by a small number of birds and that continued movement between the islands and the mainland is infrequent. If this is true, these populations could have a narrow genetic base, which might explain the limited variation noted in some of the plumage colour characteristics.

Even if some birds do continue to move infrequently from the mainland to the islands, their genetic contribution to the large local population would be small, unless there were positive selection pressure for some newly introduced character. Alternatively the effects of environment or diet could influence the colour expression, but this requires further study.

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Buller's Mollymawks on Rosemary Rock, Three Kings Islands, in 1985

In December 1983, Northern Buller's Mollymawks (*Diomedea bulleri platei*) were found breeding near the summit of Rosemary Rock at the Three Kings Islands, northern New Zealand (Wright, A.E. 1984. *Buller's Mollymawks breeding at the Three Kings Islands*. *Notornis* 31: 203-207). Previously, this subspecies was thought to breed only at the Chatham Islands, some 1600 km south-east of the Three Kings Group. When we visited Rosemary Rock in January 1985, we found 15 nests, 13 of which were occupied.

We landed on Rosemary Rock (Fig. 1) for one hour in the afternoon of 16 January 1985. During this time, the nesting area discovered and illustrated by Wright (1984) was relocated. We found that the colony described by Wright near the summit of the island comprised two incubating adults, an adult brooding a chick, and two displaying birds occupying an empty nest. Additional nests and birds were found in two separate areas, both on the south-facing slope of the island. A single bird was incubating at the western end of the island. Eight nests in the middle of the island included two unoccupied nests, two nests with an adult but no egg, three nests with incubating birds, and one nest with an adult and a young chick. In total, 12 mollymawks were seen, of which six were on nests with single eggs, two were brooding young chicks, and four were associated with three empty nests. During this visit, a total of 13 nests was found, two of which were unoccupied. One of the unoccupied nests contained old egg fragments, indicating either breeding in previous years or failed nesting during the current season.

The dimensions of 11 nests were as follows: average maximum height above the surface of the ground 90 mm (range 60-180 mm), average inside diameter 220 mm (range 200-240 mm) and average outside diameter 310 mm

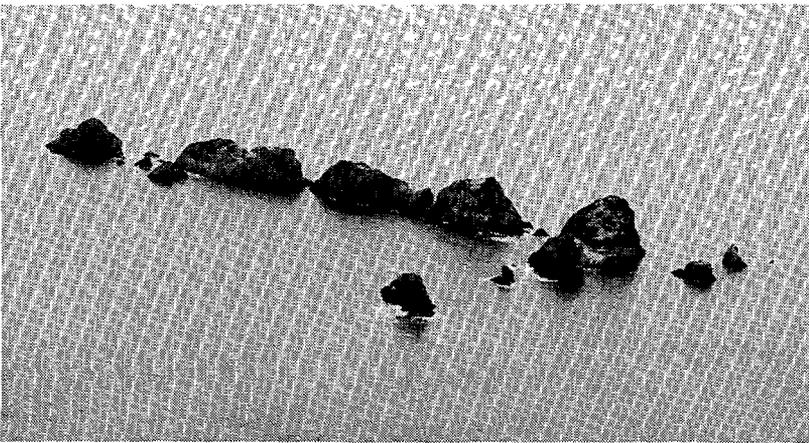


FIGURE 1 — Oblique aerial view from the south-east, showing Rosemary Rock (foreground) with islets of the Princes Chain in the rear. The mollymawks are nesting on the slope on this side of the island

Photo: D. L. Homer, N.Z. Geological Survey



FIGURE 2 — Incubating Northern Buller's Mollymawk at Rosemary Rock with yellow stripe less than half of width of lower mandible

Photo: M. P. Francis

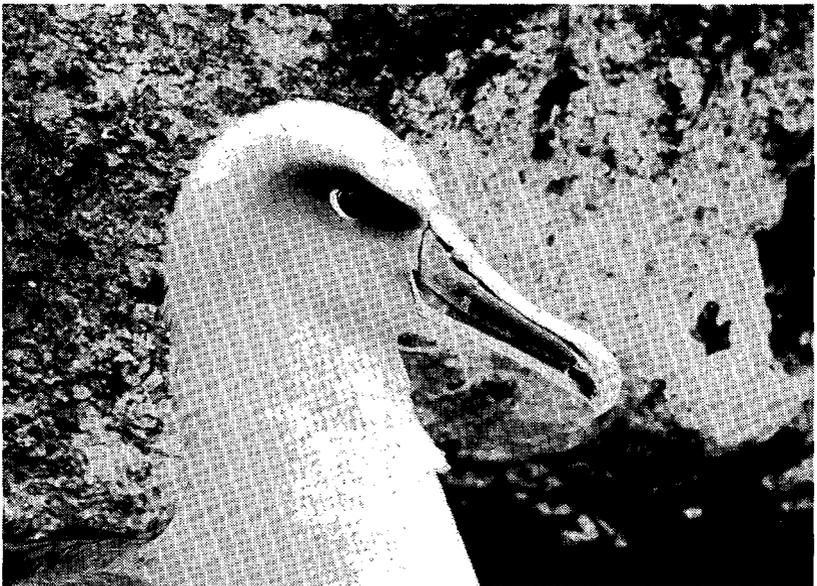


FIGURE 3 — Northern Buller's Mollymawk at Rosemary Rock with yellow stripe greater in width than half of lower mandible

Photo: M. P. Francis

(range 290-340 mm). The nests were made of dried mud and plant material. Some nests were built over an irregularly sloping rock surface and others over loose stones. Although taller nests may indicate occupancy over many seasons, the height of nests seemed to be partly related to the topography of the substrate. It may be significant that the two unoccupied nests were among the lowest in height.

Observations from the sea on 18 January revealed two additional nests on the south-facing slopes of Rosemary Rock, both occupied by a pair of adult-plumaged birds. On that day, a minimum number of birds seen was 18, including several flying above the colony.

Eight culmen measurements of adult birds at Rosemary Rock were made with a steel ruler (112, 113, 117, 117, 118, 118, 119 and 119 mm), giving a range that overlaps with both subspecies of Buller's Mollymawk (C.J.R. Robertson, pers. comm.). However, the colour of the forehead (silvery grey rather than white) and the presence of a heavy eyebrow reaching the base of the bill (Fig. 2) indicate that the birds on Rosemary Rock are Northern Buller's Mollymawks (C.J.R. Robertson, pers. comm.). This identification is confirmed by the date of hatching. During our visit, one egg was hatching while the two chicks that we saw would not have been much more than ten days old. Their culmens measured 35 mm. Laying dates of late October to early November (with a 68-69 day incubation period, C.J.R. Robertson, pers. comm.) and hatching of eggs in mid-January are characteristics of the northern subspecies from the Chathams, while the southern race (*Diomedea b. bulleri*) from the Snares and Solander Islands lays from early January to early March.

The two mollymawk subspecies have also been differentiated by the width of the yellow stripe on the lower mandible, where the stripe width is greater than 50% in the southern subspecies and less than 50% in the northern race (Robertson, *in* Wright 1984). Figure 3 shows a bird with a yellow stripe width greater than half the lower mandible. This bird is brooding a chick and fits the description of the northern subspecies. Figure 2 shows an incubating adult at Rosemary Rock with a yellow stripe less than half the width of the lower mandible. It therefore appears that the yellow stripe width is variable within the northern race and not a reliable feature for subspecific identification.

It is doubtful if the mollymawk colony on Rosemary Rock has increased dramatically since Wright's observations, although our 1985 figures of 18 mollymawks and 15 nests contrast with the six birds and five nests found in 1983. Our survey was more extensive in that we were able to examine the small ledges down the steep south-facing slope of the islet. However, the Three Kings colony should be watched regularly to assess changes in numbers and possible spread to other islands in the group.

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Blue Penguin attacked by fur seal

On Stephens Island (Marlborough Sounds) at noon on 3 November 1981, the principal lighthouse keeper, G. Schroder, drew my attention to a commotion in the sea about 5 metres from shore. We saw that an adult fur seal (*Arctocephalus forsteri*) had captured a Blue Penguin (*Eudyptula minor*).

Having been attacked from behind, the penguin was immobilised and had a large wound across its back. The seal, perhaps disturbed by our presence, abandoned the penguin to make a shallow dive, and, returning to the surface, snatched the penguin and dived again with it.

This observation confirms the suggestion of Stonehouse (1975, *The biology of penguins*, Macmillan) that "... adults of this species, like others in New Zealand waters, would be taken by fur seals and sharks ..."

Other evidence of fur seals taking penguins has been recorded by Sorensen (1969) in *Fish. Tech. Rep. NZ Mar. Dep.* 39:1-35.

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Barn Owls transported by aircraft — a postscript

In an earlier note (Gill & Turbott 1984, *Notornis* 31: 177-179) we reported a live Barn Owl (*Tyto alba*) of Australian origin at Flat Bush near Auckland International Airport. The owl's fat condition, with some food still in the gut 18 hours after discovery, argued against the bird having flown to New Zealand. It seemed just possible that the owl had arrived in the undercarriage bay of an international jet airliner.

This supposition is strengthened by a subsequent event. At about 0800 h on 12 March 1985, airport staff found the partly mangled remains of a bird in the undercarriage bay of a McDonnell-Douglas DC-10 (Continental Airlines flight CO1) newly arrived from Los Angeles via Honolulu. One of us (BJG) identified the bird as a Barn Owl. The head and one wing were undamaged. A rodent's tail protruded from the mangled thorax. Barn Owls are resident in California (Peterson, R. T. 1961, *A field guide to western birds*) and introduced to Hawaii (Berger, A.J. 1972, *Hawaiian birdlife*) where it is uncommon. The aeroplane was present at both ports during darkness.

This establishes that Barn Owls can be accidentally transported to New Zealand by jet aircraft. In this case the bird was crushed, presumably by the undercarriage mechanism, but this may not always happen, particularly in Boeing 747 aircraft, which have larger undercarriage bays.

It seems very likely that the 1983 Barn Owl at Flat Bush was not the fourth vagrant of this species to be reported in New Zealand but was an accidental stowaway on an aircraft.

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