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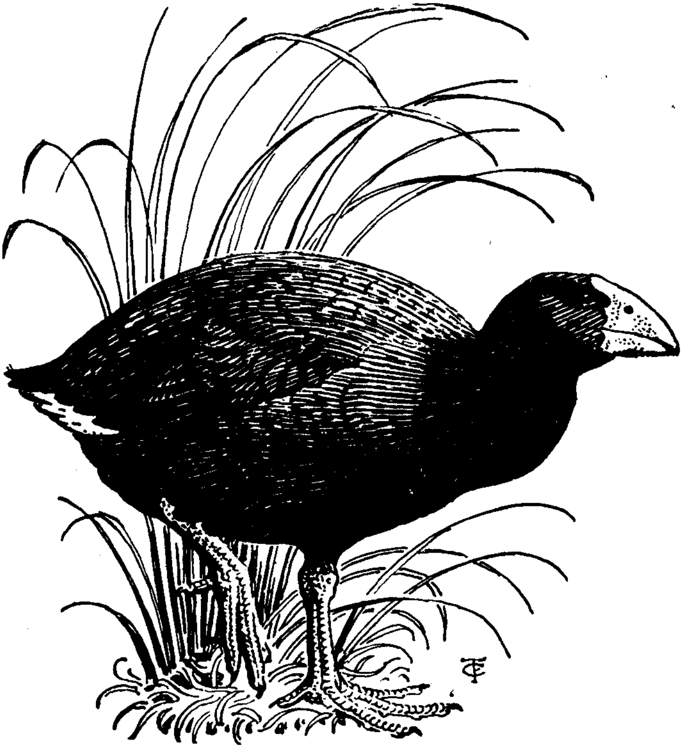

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SOME CHARACTERISTICS OF RED-CROWNED PARAKEETS ON THE POOR KNIGHTS ISLANDS

By P. M. SAGAR

ABSTRACT

Measurements, plumage and moult of Red-crowned Parakeets (*Cyanoramphus novaezelandiae novaezelandiae*) were recorded during a banding study on Aorangi Island, Poor Knights Islands, between 1978 and 1986. Males were significantly larger than females in all measurements and in weight. Weight varied throughout the year and was highest in May and lowest in November. The weights of males was significantly less during October and November than at other times of the year, but there were no significant variations in the weight of females. More males than females were caught, and recaptures suggested that females had a lower survival rate than males. Two of the 329 parakeets banded had plumage characteristics of Red-crowned x Yellow-crowned Parakeet (*Cyanoramphus auriceps auriceps*) hybrids. Casual observations indicated that the breeding season extended from late October to January. Most birds were in active moult by late February.

INTRODUCTION

Within New Zealand, *Cyanoramphus* parakeets occur on the North, South and Stewart Islands, and many offshore islands (Taylor 1985a). Although Red-crowned Parakeets (*C. novaezelandiae novaezelandiae*) were once widespread on the North and South Islands (Oliver 1955), few have been seen there in the past 25 years, and then only in large forest remnants (Bull *et al.* 1985). However, the species is still widespread and common on most islands in the Hauraki Gulf and on the Alderman Islands, Kapiti Island, Stewart Island and many of its off-liers, and the Auckland Islands (Taylor 1985a).

Although Red-crowned Parakeets are widespread, there have been few detailed studies of them. Dawe (1979) studied their food and feeding behaviour on Little Barrier and Tiritiri Matangi Islands and Nixon (1982) examined aspects of their ecology and morphology during his wider study of *Cyanoramphus* parakeets. Taylor (1985a) reviewed their status, habits and conservation in the New Zealand region.

Red-crowned Parakeets are abundant on the mammal-free Poor Knights Islands. On Aorangi Island, the smaller of the two main islands in the group, fresh water is limited to an ephemeral stream and several seeps, which attract large numbers of parakeets to drink and bathe. I took advantage of this situation to trap and band parakeets to examine particularly their measurements, weight, plumage, and moult.

METHODS

Parakeets were caught in mist nets during nine visits to Aorangi Island (35°28'S, 174°44'E) between January 1978 and November 1986. The dates of these visits are given in Table 1. Except in September-October 1981, when the nets were set at Urupa Point, all mist-netting was done at the stream in Puweto Valley. Place names mentioned in the text follow Onley (1982).

TABLE 1 — Numbers of Red-crowned Parakeets mist-netted on Aorangi Island, Poor Knights Islands, 1978-1986

DATE OF VISITS	New Birds Captured			Recaptured	
	Males	Females	Unknown	Males	Females
1-17 January 1978	-	-	10	-	-
19 February-9 March 1980	30	48	8	2	-
23 October-2 November 1980	19	10	-	2	1
5 September-11 October 1981	7	3	-	-	-
9-27 November 1981	16	4	-	1	-
23 November-8 December 1982	11	6	-	1	-
30 April-9 May 1983	56	15	-	4	1
17-27 August 1984	44	19	-	5	1
24 October-1 November 1986	17	6	-	8	-
TOTAL	200	111	18	23	3

During the first visit I recorded only weight, but on the second visit I recorded weight and wing length (length of the flattened and straightened chord). On subsequent visits bill length (from the anterior edge of the cere to the tip of the upper mandible), bill width (distance across the widest part of the upper mandible), and tarsus were measured to the nearest 0.1 mm with vernier calipers; wing length and tail length to the nearest 1.0 mm using a stopped steel ruler; and weight to the nearest 1.0 g using a 100 or 300 g Pesola spring balance. All birds captured were examined for moult.

Bill size is a reliable indicator of parakeet sex (Nixon 1982). Therefore bill length was plotted against bill width. The measurements cluster into two distinct groups (Figure 1), and birds with larger bills were assumed to be males. The wing length and weight of parakeets captured in February-March 1980 were compared with a plot of these measurements recorded from all birds sexed on the basis of bill size. Most birds captured in February-March 1980 could be assigned to a sex because the plot of their wing length and weight fell well within the cluster of measurements for assumed males and females.

Systematic observations of parakeets were confined to those captured while mist-netting, and all other aspects of parakeet biology reported are anecdotal.

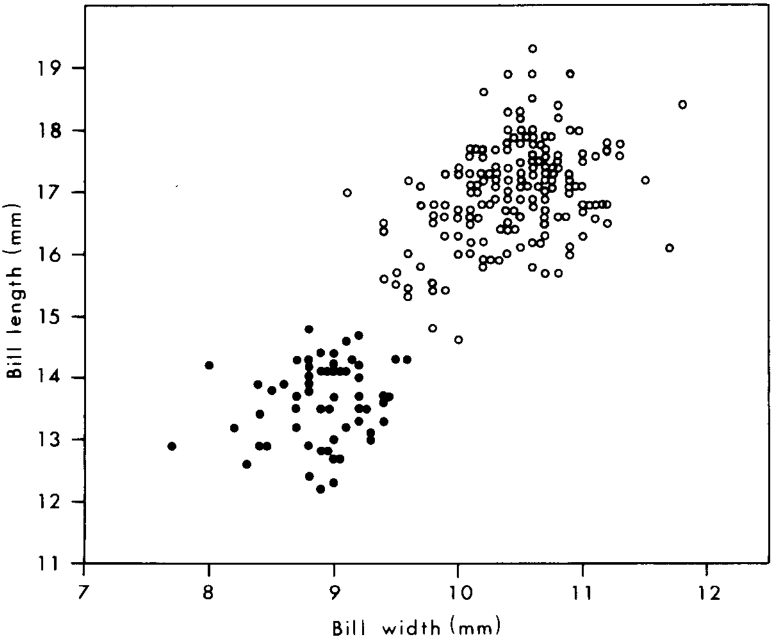

FIGURE 1 — Bill length and bill width of assumed male (o) and female (•) Red-crowned Parakeets captured on Aorangi Island, Poor Knights Island

RESULTS

Measurements and weight

A total of 355 parakeet captures, involving 329 birds, were made (Table 1). About twice as many unbanded males as females were caught, but recaptured males outnumbered recaptured females by about 8:1. The longest interval between banding and recapture was 6 years, 8 months and 3 days, for an adult male banded on 25 February 1980 and recaptured on 28 October 1986.

Males were significantly larger ($P<0.001$) than females in all measurements and in weight (Table 2).

TABLE 2 — Measurements and weight of Red-crowned Parakeets on Aorangi Island, Poor Knights Islands

		$\bar{x}$	SD	Range	N
Bill length	M	17.0	0.79	14.6-19.3	180
	F	13.6	0.63	12.2-14.8	62
Bill width	M	10.4	0.46	9.1-11.8	174
	F	8.9	0.36	7.7- 9.6	59
Tarsus	M	21.1	0.84	19.9-23.2	14
	F	20.2	0.85	18.9-22.0	11
Wing length	M	130.4	5.01	114-142	143
	F	122.7	5.27	104-135	54
Tail length	M	133.9	13.68	99-164	55
	F	125.9	12.03	103-147	22
Weight	M	82.1	8.80	63-113	181
	F	67.9	7.48	50- 90	64

Weight varied during the year (Figure 2). The mean weights of males and females were highest in May and declined gradually from August to November. By February-March the weights had increased. The pattern of weight change was similar for both males and females, but the degree of weight change was greater for males. Analysis of the weight data using single factor analysis of variance (ANOVA) and Student-Newman-Keuls procedure (Sokal & Rolf 1969) showed significant differences ($P<0.05$) in the weights of males between February to September and October to November. There was no significant difference ($P>0.05$) in the weights

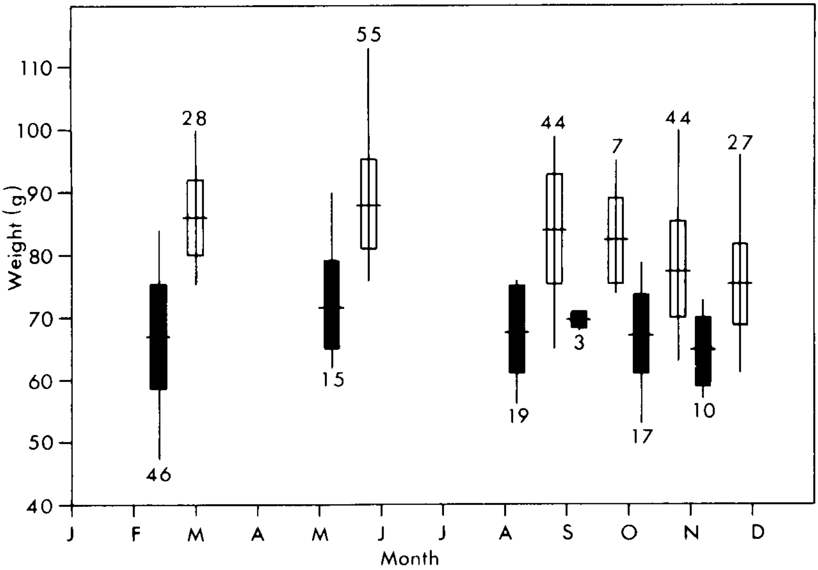

FIGURE 2 Mean (± SD) and range of weight of male (open bars) and female (closed bars) Red-crowned Parakeets at different times of the year. The plot of female measurements has been offset for clarity. Numbers indicate sample size.

of females between any months. Males lost proportionally more weight than females (14.8% cf. 9.7%) during spring.

Plumage and moult

Four of the 329 parakeets captured had plumage colouration different from that of a typical Red-crowned Parakeet. One bird had a single yellow feather on its back and two birds had an orange band across the hind edge of the crown. When one of the latter birds was recaptured 15 months later, it still showed the same colour variation. The fourth bird had a patchy red and yellow crown. Most of the crown feathers were red and yellow, yellow being particularly noticeable at the base of the feathers. Measurements of these birds lay within the range for Red-crowned Parakeets caught in this study.

Active moult was recorded during February and March 1980 and May 1983. In February-March, of the 88 parakeets captured 63.6% were in old plumage, 31.8% were in moult and 4.6% had new plumage. Of the 28 birds in moult, nine were in primary moult, 16 were moulting the coverts, 14 the crown and three the tail feathers. Most parakeets were in new plumage by May, and the only moult recorded was in the crown feathers of five of the 76 (6.6%) captured. Some birds had tail feathers missing at other times of the year, but because these feathers are loose I did not consider their loss to be a sign of active moult.

Behaviour

On all visits parakeets were seen to commute between the main islands of the group, a distance of about 150 m. Parakeets usually moved about Aorangi in pairs throughout the year but groups of up to eight birds were seen occasionally. Whenever a parakeet was caught it was usual for another to fly about the net in an agitated manner.

Between January and March, single parakeets were often found roosting in hollow sections of cabbage trees (*Cordyline* sp.) at night.

Feeding

In January parakeets were seen to feed on the seed heads of the jointed rush (*Leptocarpus* sp.) and toetoe (*Cortaderia richardii*). Grasping the base of the seed head with the bill they pulled the seed head through the bill to dislodge the seeds into the gape. They were also seen to eat ripe seeds of *Coprosma macrocarpa* and *Macropiper exulans.*

From February to May parakeets were seen to eat only the seeds of karo (*Pittosporum crassifolium*), opening the top of the soft unripe seed capsule and removing the seeds. Occasionally they fed on capsules which had fallen to the ground.

In August, parakeets fed on karo which were dispersed among the litter, husking the seeds and eating only the kernel. They ate only seeds which were on the surface and did not scrape the litter.

In October and November the only food they were seen to take was the flowers of pohutukawa (*Metrosideros excelsa*). The parakeets seemed to bite off the flower heads and chew the stamens before dropping the flowers.

Breeding

Nesting burrows in the banks of the Puweto Valley stream were cleaned out at about the end of October. On 3 January a nest containing three small young was found in a burrow near the top of the stream bank. The nest chamber was 100 mm from the burrow entrance and droppings lined the lower half of the rim. An adult brooded the young during the nights of 3 and 10 January. No active nests were found during other visits, indicating that breeding had finished by mid-February.

DISCUSSION

The capture of 329 Red-crowned Parakeets during this study demonstrates the abundance of this species on the Poor Knights Islands. Unfortunately too few recaptures were made for me to estimate the size of the population and survival rate of the parakeets. The movement of the parakeets between islands probably had much to do with the low recapture rate.

The predominance of males captured may be a true reflection of the sex ratio of the parakeet population but, in part, it may also be a result of different behaviour, such as males moving about more than females.

However, the even greater predominance of recaptured males suggests that males have a higher survival rate than females. This aspect of the parakeet population on the Poor Knights Islands needs more study.

This study extends the ranges of measurements quoted by Oliver (1955), Forshaw (1973) and Nixon (1982). This is to be expected, however, because previously only small samples (usually fewer than 10 birds) had been measured.

The weight of birds is influenced by environmental and ecological factors. Activities associated with breeding may have resulted in the weight loss from October to November. The male feeds the female during incubation and assists with feeding the young (Taylor 1985b) and this probably accounts for the significant weight loss by males during October and November, compared with no significant weight loss by females during the same period. Presumably foods supplies were reduced during winter (May to July) because the weights of both sexes declined from May to August. Presumably recently fledged birds were among the parakeets captured during February-March 1980. However, as these were not identified I cannot tell whether they affected the range of weights.

The presence of a few parakeets with orange in the crown suggests interspecific hybridisation. The head pattern of two of these birds was similar to the lower left illustration of *C. n. chathamensis* x *C. a. forbesi* hybrids recorded by Taylor (1975), thus suggesting Red-crowned x Yellow-crowned hybridisation. The report of two possible Yellow-crowned Parakeets (*C. auriceps auriceps*) by Chambers (1956) and the presence of these hybrids indicates that Yellow-crowned Parakeets may reach the Poor Knights from the adjacent mainland (a distance of 20 km) or from the Hen and Chicken Islands 45 km to the south. The only previous report of parakeet hybridisation in unmodified habitats is from Little Barrier Island, where Veitch (1979) recorded a Red-crowned interbreeding with a Yellow-crowned Parakeet. This situation contrasts with that where the habitat has been drastically modified and hybrids occasionally become locally abundant, as on the Auckland Islands (Taylor 1975, 1985a, 1985b). On the Poor Knights hybridisation probably occurred because of a lack of conspecifics, but on the Auckland Islands the highly modified habitat and rarity of conspecifics both apply (Taylor 1985a).

Movements of *Cyanoramphus* parakeets between islands to feed is not unusual. Fleming (1939) reported that Chatham Island Red-crowned Parakeets (*C. n. chathamensis*) and Forbes' Parakeets (*C. a. forbesi*) flew the 2.5 km from Mangere Island to Pitt Island to feed on seasonally available flowers and fruit. Kinsky & Sibson (1959) also reported Red-crowned Parakeets feeding on toetoe and moving between islands in the Poor Knights group.

The breeding season of Red-crowned Parakeets on the Poor Knights Islands (late October to January) is shorter than that recorded on the mainland and the near-shore Tiritiri Matangi Island (August to April) by Dawe (1979). Gill & McLean (1986) commented that there is evidence that birds have shorter breeding seasons on islands than on the mainland, but whether this results from low food supply, high population density, or some other factor is not known. The breeding season of Red-crowned Parakeets is timed to match the food supply (Taylor 1985a), but on the Poor Knights the shorter breeding season may be due to high population density.

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BREEDING OF THE BANDED DOTTEREL, *Charadrius bicinctus*, ON THE CASS RIVER DELTA, CANTERBURY

By MARY BOMFORD

ABSTRACT

Laying began in August, peaked in late September to early October and finished in December. Eggs were laid at intervals of three days to a normal clutch of three. The site and dimensions of 47 nests are described. The female did 82% of daytime incubating, and incubation averaged 26.5 days. Most eggs were lost to predators and only 44% hatched. In fine weather chicks made trips away from the nest within a few hours of hatching. Once hatching was completed the nest was deserted, but parents and chicks stayed in the territory until the chicks fledged at 5-6 weeks. Post-breeding flocks contained 23% juveniles.

INTRODUCTION

There has been no comprehensive study of the Banded Dotterel's breeding biology, and only Stead (1932), Stidolph (1971), Child (1970), Soper (1972) and Phillips (1980) have published some observations on breeding dates, habitats and behaviour at the nest. This study describes nest construction and breeding performance in a typical high-country breeding site. All observations were made between July 1977 and January 1978.

STUDY SITE

The study site was the Cass River Delta, west of Lake Tekapo, Canterbury (Figure 1). The greywacke shingle of the delta is dissected by shallow dry stream channels and is stabilised by mat plants, the main species being common raoulia *(Raoulia hookeri)*, scabweed *(Raoulia australis)*, the moss *Racomitrum ptychophyllum*, white clover *(Trifolium repens)* and various grasses, mainly *Poa* spp. More detailed descriptions of this site are given by Bomford (1978) and Pierce (1983).

METHODS

Nests were visited on foot twice a day during laying and hatch, and every second day during incubation. All eggs were marked with pencil to show the order they were laid in. The hide used to observe nests was a one-man tent erected about 20 m from the nest on the evening before the observation day.

RESULTS

Territories: The first isolated breeding pair of birds was seen on 2 August, and from the second week of August onwards many pairs were seen actively defending territories against intruders. The displays and behaviour used for territorial defence are described by Bomford (1986).

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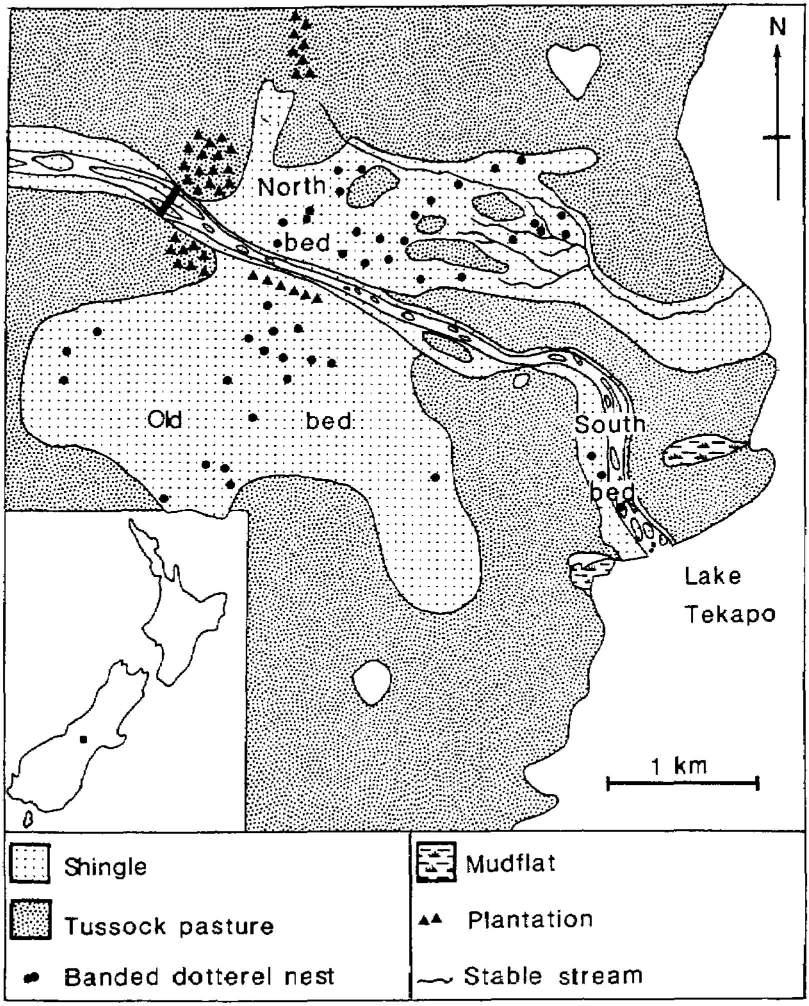

FIGURE 1 — The Cass River delta study area. At the time of the study the Cass River flowed down the south bed. In the past century the river twice changed course and the north bed and the old bed are both stable shingle beds left from these times. Nests marked on the map were not all present at the same time, and not all nests on the delta were found.

Nests: Nests were scrapes in loose shingle or sand. To scrape out a nest, a bird would sit, pivot on its breast and kick backwards. The nest was lined before eggs were laid with small fragments of grass, leaf, moss, dung or stones, which the bird picked up from the surrounding shingle and threw back over its shoulder towards the nest. The bird then sat in the scrape, collecting these fragments in its bill and placed them in the nest. About 90% of nest scraping and lining was done by males. The amount of lining varied between nests from none to a layer 2-3 cm deep.

The dimensions of 47 nests were mean depth 32 ± 5 mm (1 SD) and mean diameter 97 ± 7 mm. Of these 47 nests, 46 were on shingle stabilised by mat-plants. The exception was on an island in the main river, a site that was flooded later in the season. The ground surrounding 46 of the nests was level or very gently sloping, and only one nest had a rise nearby that would have blocked much of the incubating bird's view of its surroundings.

Nests were not made beside large stones or other objects that would have protected the incubating bird from the prevailing winds, which were often strong. By contrast, the nests of Wrybills *(Anarhynchus frontalis)* on the delta were often against a protecting stone or piece of driftwood. Banded Dotterels did not nest in areas with small bushes or shrubs such as the common matagouri bushes *(Discaria toumatou)*, which grew on the oldest, most stable shingle beds.

Laying: Six empty nests were checked daily before the first egg was laid, and so I recorded the laying times of all eggs in these nests. I found six more nests while they had only one egg, and so I recorded the time interval between the second and third eggs. I estimated the average interval between the laying of first and second eggs as 87 ± 28 (1 SD) hours, and the interval between the second and third eggs was 66 ± 13 h.

Figure 2 gives the estimated laying dates for the first egg in 35 nests. When I did not know the date the first egg was laid, I estimated it by counting back from the date the second or third egg was laid, or from the date of hatching, allowing 26.5 day for incubation. The first egg of the season was found on 22 August, and a second egg was found in the same nest on 25 August. On 28 August this scrape still had only 2 eggs, and incubation had not started. That night the eggs were covered by 5 cm of snow, and next morning Banded Dotterel tracks in the snow showed unsuccessful attempts to visit the nest. On the morning of 31 August the snow had melted but the eggs were gone. Laying spread from mid-August to mid-December, but peak laying was in late September and early October.

The weights of 51 eggs were recorded either before incubation started or within 24 h of laying. The mean weight was 11.5 ± 0.8 g (1 SD).

The ground colour of eggs was usually pale aqua or pale olive green, but a few were light grey or light brown. Eggs were marked with black or brown spots, blotches or squiggles. During laying the male was very active in adding lining to the nest, and before incubation started many nests had eggs that were almost buried in lining material which matched them in colour and pattern and formed an effective camouflage (photograph *in* Bomford 1978).

A nest with an incomplete clutch of two eggs was observed from a hide from 0500 h to 1930 h on a sunny day on 16 October. Incubation did not start in this nest until the third egg was laid two days later. At dawn the nest was unattended, and between 0600 h and 0900 h the nest was visited only 3 times by the male, which stayed on the eggs for less than a minute each visit and added lining material to the nest for several minutes when he left. Between 0900 h and 1230 h the nest was visited more frequently by both parents, and in this period the eggs were sat on about half the time, mainly by the female. Between 1230 h and 1620 h the eggs were sat on almost continuously by the female. This behaviour would have shaded the eggs and perhaps prevented them from overheating in the hot part of the day when the shingle surface temperature reached well above incubation temperature. At 1620 h the female left the nest, and from then until dark at 1930 h it was infrequently visited by the male, which again added lining material after each visit. In total, the eggs were sat on for 34% of the daytime.

Of 40 nests in which the eggs were incubated, 36 had 3 eggs, 2 had 2 eggs, and 2 had 1 egg. I do not know whether the smaller clutches had lost eggs or were complete.

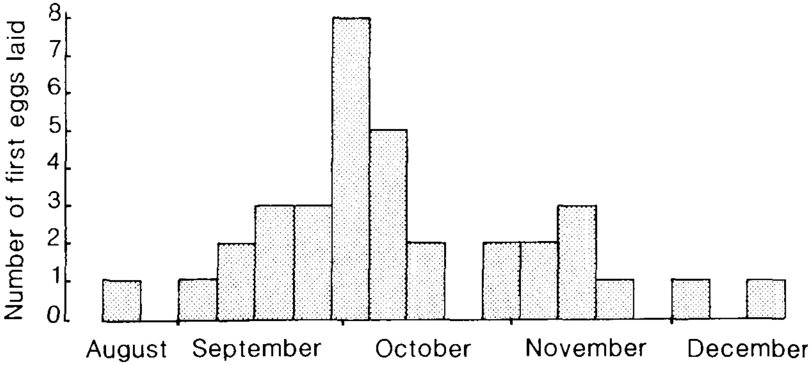

FIGURE 2 — Laying dates (first egg) for clutches found on the Cass River Delta in the 1977-78 breeding season

Incubation: Once incubation started, the eggs were placed on top of the nest lining, rather than being buried in it. They were arranged haphazardly, not neatly with the pointed ends inwards (photograph *in* Bomford 1978).

In two early nests with clutches completed on 17 and 20 September, continuous incubation did not begin until 4 and 5 days after the third egg was laid. In all other nests incubation started within a day either side of the third egg being laid, except in two late nests, in which the clutches were not completed until 10 November and 7 December and in which incubation started two days before the third egg was laid.

I made dawn to dusk observations from hides of eight nests at different stages of incubation, giving a total of 109 hours of observation. The female averaged 82% of the daytime incubating, ranging from 67% to 99% for individual nests, and there was no tendency for the male to do more daytime incubating as hatching approached. Only 1 of the 11 birds observed incubating at last evening light was a male, and this contrasted with observations made at first morning light, when 8 of 10 incubating birds were males. These data suggest that males may do a greater share of the night-time incubating.

The eggs were incubated for 93% of the daylight hours and were not left unincubated for more than 10 minutes. The incubating bird left the nest for short periods to throw lining material on the eggs, to feed or preen nearby, to chase an intruder from the territory, or when the parents changed over or predators were close.

In the eight nests observed from hides, the average time between change-overs was 177 minutes, ranging from 10 to 570 minutes. The non-incubating bird often stayed feeding or resting within 100 m of the nest, but sometimes left the territory.

Owing to a high level of nest predation, incubation periods were recorded for only four clutches. These were 26, 26, 26.5 and 27 days ± 1 day for each observation. Each period is taken from the laying of the last egg to the hatching of the last chick, and nests in which there was a delay between clutch completion and the start of incubation are not included in the sample.

Nest predation and egg loss: Despite the cryptic colouring of eggs and the willingness of parents to perform distraction displays (Bomford 1986), 56% of eggs were lost before hatching. The history of 37 clutches is known. Three clutches (5 eggs) disappeared during laying, 17 clutches (50 eggs) were lost during incubation, 16 clutches (44 eggs) hatched, and 1 clutch, consisting of a single egg half buried in lining in a scrape, was not attended by adult birds from the day it was found. This deserted egg was found to have an apparently normal yolk. Four of the successful nests hatched only 2 eggs: one 2-egg clutch, one cracked egg, one infertile egg, and one egg that disappeared from a nest during incubation.

The disappearance of eggs was attributed to predators but I could not identify the species responsible. Most eggs simply disappeared, but sometimes trace of egg yolk and shell were found in a nest, and one nest had three opened eggshells.

Hatching: Hatching was recorded for eight nests. The time interval between hatching of the first and third eggs ranged between 20 and 45 hours. In the four nests for which I recorded both laying and hatching, the eggs hatched in the order they had been laid in.

One or two days before an egg starred, the chick could be heard peeping inside the egg. Eggs hatched 2-50 h after they starred. Within minutes of hatch the incubating parent flew away with the large pieces of eggshell and dropped them 5-25 m from the nest. Smaller pieces were tucked under the nest lining. The mean weight of 32 chicks, weighed within 24 h of hatch, was 8.0 g ± 0.4 (1 SD). The colours of 36 downy chcicks were recorded: 18 were grey and white, 13 were gold or gold and white, and 5 were grey and gold. All chicks had black spots on the head, back and upper wings and white underparts.

In fine weather, chicks made trips away from the nest within 3-4 h of hatch, but at night or in bad weather they stayed in the nest, sometimes for over a day. At first chicks went only 1-2 m from the nest but soon moved around the whole territory. They pecked at the ground on their first trip and soon fed.

Chicks were seen in the nesting territory until fledging at 5-6 weeks of age. As feathers replaced down they spent less time being brooded and more time feeding, but both parents stayed in the territory with the chicks. Colour bands were put on 48 chicks, but their secretive behaviour and cryptic colouring made it impossible to follow survival rates. After fledging, parents and juveniles left the territories to join the post-breeding flocks. These flocks, seen from mid-December onwards, ranged in size from 4 to 40 birds, averaging 20. Of 497 birds observed in post-breeding flocks, 23% were juveniles.

DISCUSSION

Boyd (1962) made the generalisation that in the Charadrii 66-96% of eggs hatch, and Cramp *et al.* (1983) gave a similar range for *Charadrius* plovers in Europe. The low level of 44% in the present study could be caused by a lack of adaptation to introduced mammalian predators. Phillips (1980) found that only 12 of 116 (9%) Banded Dotterel eggs hatched in a North Island breeding ground, although most of his egg loss was caused by flooding.

Females did most of the daytime incubating throughout the incubation period in the present study, and the relative sitting times of the sexes did not change as incubation advanced, or during hatching. This contrasts with Soper's (1972) observation that "As incubation advances the male takes over a larger and larger share of the duty". Phillips (1980) also observed that female Banded Dotterels do most of the incubating. The present study indicated, however, that males probably play a greater role in night-time incubating. The male's major role was in territorial advertisement and defence and in nest construction. The method of nest construction was remarkably similar to that described and illustrated by Rittinghaus (1961) for the Kentish Plover *(Charadrius alexandrinus)*.

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FORAGING BY ADÉLIE PENGUINS DURING THE INCUBATION PERIOD

By L. S. DAVIS, G. D. WARD and R. M. F. S. SADLEIR

ABSTRACT

Nine Adélie Penguins (*Pygoscelis adeliae*), 4 females and 5 males, were tracked by radio telemetry when they went to sea from the Northern Rookery, Cape Bird, Antarctica, on their first foraging trips of the incubation period. Each penguin took a different direction on leaving the rookery but maintained its approximate heading, suggesting that it was navigating. Radio contact was lost after 2-12 days as birds moved beyond the 100 km radio horizon. The penguins spent about one-third of their time on ice floes. Most of their time in the water was spent diving and feeding. Dives (including underwater swimming) lasted for a mean of 92.5 s, followed by a mean recovery period of 33.8 s. The length of the recovery period was significantly correlated with the length of the dive. From the maximum dive times, the duration of "feeding" dives, and the dive: pause ratios, Adélie Penguins seem to have diving abilities between those of the other two pygoscelid penguins, the Gentoo and Chinstrap. We hypothesize that the Adélie Penguins may travel large distances from the rookery during the incubation period so as to forage on the larger and more pelagic krill, *Euphausia superba*.

INTRODUCTION

Adélie Penguins (*Pygoscelis adeliae*) feed mostly on krill, small euphausiid shrimps (Emison 1968, Lishman 1985). Observations from ships suggest that the penguins forage mainly in association with the pack ice (Fraser & Ainley 1986). Chicks must be fed regularly, and the average trip to sea after their chicks have hatched lasts only 1-2 days (Penney 1968, Davis 1982a). However, while the eggs are being incubated, each parent makes one long foraging trip to sea: first the female is away for about 17-19 days, and then the male goes for about 13 days (Davis 1982b, in press). Birds not returning from these long foraging trips in time to relieve their mates on the nest are a major cause of breeding failure (Davis & McCaffrey 1986). Where, then, do the penguins go on these long trips at sea? If they forage close to the rookery, they would presumably return more often, making breeding failure less likely.

We know little of what Adélie Penguins do once in the water because they are hard to follow in the ice-filled waters of Antarctica. Trivelpiece *et al.* (1986), to track Chinstrap (*P. antarctica)* and Gentoo (*P. papua*) Penguins at sea, used small radio transmitters attached to the penguins' backs and two land-based receiving stations. They also demonstrated that differences in the signals received were associated with different activities of the penguins. We used the same technique on Adélie Penguins during the incubation period.

NOTORNIS 35: 15-23 (1988)

METHODS

This study was made from the Northern Rookery at Cape Bird, Ross Island, Antarctica (77 ° 13′ 10″ S, 166° 28′ 30″ E), between 17 November and 16 December 1985.

Each transmitter (Austec Electronics model KG80) was sealed in a waterproof, streamlined package, together with three 1/2AA lithium cells that gave a theoretical transmitting life of 28 days. Its total weight was 50 g. It was fixed by epoxy resin to the feathers on a penguin's back and switched on by means of a reed switch.

Two tracking towers were established: one on New College Hill (230 m above sea level) and the other on Inclusion Hill (338 m above sea level) (Fig. 1). The baseline distance between the two towers was 2742 m. Each receiving antenna consisted of a single 6-element yagi antenna mounted on a rotatable 5 m mast fitted with a compass rose. Custom Electronics CE12 and Merlin 12 receivers were used to receive signals from the transmitters in the 160.1-160.3 MHz waveband. The maximum radio horizon was 75 km from Inclusion Hill and 60 km from New College Hill. The signal of the transmitters was strong enough to be received at up to 100 km, provided that the receiving antenna was high enough (i.e. 600 m). For example, strong signals were received at 600 m when transmitters were tested between Cape Bird and Cape Roberts, a distance of 83.2 km.

In addition, a 3-element yagi antenna mounted on the outside of an Iroquois helicopter was used to search for birds if they moved beyond the range of the land-based antennae. The helicopter was not permitted to fly over open water, and so the procedure was to hover about a known landmark at 600 m and make a systematic scan search to seaward.

Ten birds (4 females, 6 males) had radio transmitters attached to them between 17 and 23 November. From 18 November the tracking towers were manned for 1-2 hours each day (usually between 1530 and 1730). A systematic search was made for each bird that was at sea, and if located, its direction was fixed by taking the mid-point between the two null-points of the signal. Locations and distances were calculated later by triangulation.

In addition, because transmissions could be received only when the transmitter aerial was above the surface of the water, the activity of the animal could be deduced from the signal, rather as Trivelpiece *et al.* (1986) did: (a) a continual, regular signal indicated that the bird was out of the water and so probably on an ice floe; (b) a regular signal interspersed with periods of silence indicated that the bird was diving (either foraging or swimming underwater) with recovery periods at the surface; and (c) an irregular signal indicated porpoising (confirmed when a porpoising penguin was seen while being radio-tracked) and short bursts of signals from the surface were associated with swimming. If the bird was diving and signal strength was good, focal animal sampling was done to measure duration of dives and duration of recovery periods at the surface.

To check the accuracy of land-based fixes, a helicopter was used to take four readings of a bird from the other side of McMurdo Sound. At distances of around 40 km and over a baseline of 46 km, the helicopter fixes gave the bird's position as within 6 km of the position given from the land-based towers 2 hours later. This would indicate an approximate error of±1° in the land-based fixes. The effect of such an error on the accuracy of calculated locations of foraging penguins depended on the orientation of the penguin to the baseline of the tracking towers. The location of a penguin foraging at 20 km perpendicular to the baseline could be fixed with an accuracy of ±3 km, but a bird 20 km away more-or-less in line with the baseline could have been calculated as being anything from 10 km to 70 km away. However, a crude indication of distance could also be derived from the signal strength, as typically the further a penguin was away, the weaker was the signal. Although signal strength varied according to atmospheric conditions, it could be used as a rough check on the calculated locations of the penguins.

We left Cape Bird on 16 December. The average length of foraging trips was 19.0 days for females (SD = 3.4, n = 23) and 12.6 days for males (SD = 2.7, n = 23) during the 1985/86 season (Davis, in press), and so, as we had expected, most birds did not return to the rookery before the end of the study. One male (#5) did not go to sea at all, remaining on his nest throughout the study. Of those birds that went to sea, only #10 returned before 16 December. In January 1986 another field party staying at Cape Bird saw three more and retrieved the radios from two of them. Finally, in a thorough search of the colonies by one of us (LSD) during the courtship period the following season (1986/87), 7 of the 10 birds that had been carrying transmitters were found (unretrieved transmitters would have fallen off when the penguins moulted at the end of the breeding season).

On 5 December a storm damaged the antenna on Inclusion Hill, making accurate fixes possible only from a helicopter. However, by then all birds (except #5) had gone to sea and only three remained in radio contact. Their direction and signal strength continued to be monitored daily from New College Hill, and their positions were checked from a helicopter when possible.

Directions are given in degrees, north being 0°.

RESULTS

Patterns of departure

Nine of the 10 radio-tagged Adélie Penguins (4 females, 5 males) went to sea. Their mean direction taken on the day of departure from the rookery was 324° (SD = 40, n = 9) (Table 1).

One radio (#10) emitted intermittent signals and functioned for only a few hours. When recovered later it was found to have been corroded after water penetration. The rest produced normal signals and were tracked

TABLE 1 — Results of radio tracking nine Adélie Penguins as they left the Northern Rookery, Cape Bird, on their first foraging trip of the incubation period. Shown are the initial and final recorded directions of the penguins from the rookery (0° = north), the duration of radio contact, the maximum recorded distance from the rookery (km), and whether they were known to return to the rookery

Penguin	Sex	Date Depart	Initial Direction	Days to Last Contact	Final Direction	Maximum Distance	Return
#1	F	20/11	312	12	303	44	Y
#2	F	19/11	13	3	59	23	N
#3	M	1/12	266	2	216	26	Y[2]
#4	F	18/11	293	2	276	63	N
#6	M	4/12	300	2	294	40[1]	N
#7	M	3/12	313	5	17	60[1]	Y
#8	M	28/11	311	11	13	24	Y[2]
#9	M	22/11	1	12	102	60	Y
#10	F	24/11	24	0	(24)	-	Y[2]

[1] deduced from signal strength

[2] radio recovered

for a mean of 6 days (range 2-12). The two that were recovered were undamaged.

The loss of radio contact with these eight birds after 2-12 days, then, was almost certainly due to the animals moving beyond the radio horizon (i.e. 100 km from a searching helicopter). The evidence for this is threefold: (i) mean distances of penguins from the rookery increased each day ($\underline{r} = 0.70$, $P < 0.01$, $n = 13$), (ii) the last contacts were usually associated with faint signals indicating transmitters operating close to the limits of their transmitting distances, and (iii) when contact was lost with the two land-based antennae, contact was sometimes re-established from the helicopter, which had a larger radio horizon and larger search area.

The final direction of the foraging penguins, before they went beyond the radio horizon, was quite variable ($\bar{x} = 345°$, SD = 78, n = 9) (Fig. 1). However, two basic patterns were apparent: four penguins went in a westerly direction across McMurdo Sound; while the other five headed in a north-easterly direction, past Beaufort Island and east of the tip of Cape Bird. The final direction for each penguin was highly correlated with the initial direction it took when leaving the rookery ($\underline{r} = 0.91$, $P < 0.01$, n = 8 excluding #10), suggesting that the penguins were navigating and not just moving randomly.

Behaviour at sea

A rough approximation of the proportion of time penguins spent in each activity was determined from 33 observations where the signal was certain: swimming/ porpoising, 24%; diving/feeding, 42%; and on ice floes, 33%.

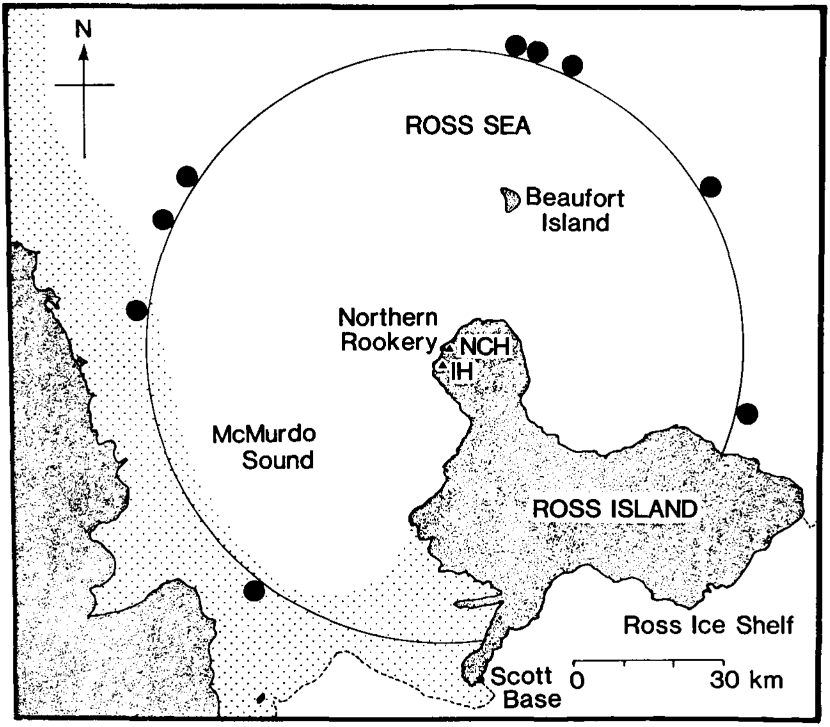

FIGURE 1 — Final recorded directions of Adélie Penguins (n = 9) departing from the Northern Rookery, Cape Bird, on their first foraging trips of the incubation period. The horizon is set at 60 km, which was the maximum radio horizon from New College Hill and corresponded with the maximum recorded distances of penguins from the rookery (see Table 1). The positions of the tracking towers on New College Hill (NCH) and Inclusion Hill (IH) are shown, and the lightly stippled area represents the approximate extent of the sea ice at the time of this study

Diving/feeding times and the associated recovery period at the surface were recorded for 108 dives from four penguins (#1, #3, #7, and #8) (range 15-43 dives each). The mean dive time was 92.5 seconds (SD = 45.1, n = 108), and the mean recovery period was 33.8 seconds (SD = 32.9, n = 108). The recovery time was significantly correlated with the duration of the dive ($r = -0.63$, $P < 0.001$), the longest dives being followed by the longest periods at the surface. To distinguish between underwater swimming and feeding dives, the latter were taken to be dives exceeding 60 seconds in a sequence of at least two such dives. The mean "feeding" dive was 114.9 seconds (SD = 29.7, n = 72) and the mean recovery period 44.6 seconds (SD = 35.2, n = 72, giving an average dive : pause ratio of 2.58 : 1. The dive : pause ratio varied, however, and tended to diminish as the mean duration of dives increased (r = -0.90, P $<$ 0.1, n = 4) (Table 2). The maximum dive recorded was 182 seconds.

Use of radio telemetry

We could not tell whether wearing radio transmitters affected the length of the penguins' foraging trips because most birds were not expected to return to the rookery before the study ended on 16 December. Males #8 and #9 had deserted their nests and so were not expected to return to their colony until the reoccupation period (Davis 1982a), beginning in late December. Both were seen back in their colonies the next season. When the study ended on 16 December, the times that the other three males (#3, #6, and #7) had been at sea still had not exceeded one standard deviation from the average foraging trip for males. The following season only #6 failed to return to the rookery. However, while all four females (#1, #2, #4, and #10) had been due to return before 16 December, only #10 did so. Next year #10 and #1 were back on a nest. The radioed bird that did not go to sea during this study (#5) also returned the next season. Although male #6 and females #2 and #4 may have died, they need not have died because of wearing radio transmitters, as an annual mortality of 30% is within normal limits for Adélie Penguins.

TABLE 2 — Feeding dives of Adélie Penguins (i.e. dives longer than 60 seconds and in a sequence of at least two such dives). Times are given in seconds (mean ± SD)

Penguin	n	Dive Time	Recovery Time	Dive : Pause Ratio	Maximum Dive
#1	15	140.8 ± 8.2	105.7 ± 15.0	1.33	156
#3	17	105.8 ± 37.4	32.0 ± 15.5	3.31	182
#7	15	111.3 ± 25.2	32.5 ± 22.3	3.42	156
#8	25	107.7 ± 27.1	23.6 ± 9.1	4.59	171
Overall	72	114.9 ± 29.7	44.6 ± 35.2	2.58	182

DISCUSSION

Patterns of departure

Where Adélie Penguins go once they leave the land is still a mystery. In the ice-filled waters of Antarctica, telemetry offers the only practical way to solve that mystery. As a first attempt at radio tracking Adélie Penguins, this study has shown that telemetry can be successful; but it has raised more questions about the penguins than it has provided answers.

Clearly, both male and female Adélie Penguins travel long distances, over 100 km from the rookery, on their first foraging trip of the incubation period. The direction each penguin takes is variable, though each appears to keep roughly to its path. Thus, the penguins may be navigating, especially as on ice floes, where they spent one-third of their time, wind and currents would take them off course. Adélie Penguins have been shown to be quite capable of navigation (Emlen & Penney 1964).

Where, then, are they going, and why? The diving records indicate that they are able to feed near to the rookery. So why do they go so much further, risking loss of eggs and chicks through desertion and starvation (Davis 1982b, Davis & McCaffrey 1986)?

The diet of penguins returning to Cape Bird during the incubation period, analysed while we were there (van Heezik 1988), consisted mostly of the smaller krill species, *Euphausia crystallorophias*. By contrast, on the Antarctic Peninsula (Lishman 1985) and at Cape Hallet (Logan, pers. comm.) Adélie Penguins feed mainly on the larger *E. superba*. Little is known of the seasonal patterns of abundance of the two krill species in the waters off Ross Island. *E. superba* is the more pelagic species and is not abundant close to Ross Island (Marr 1962). It was not a major food of penguins sampled at Cape Bird (van Heezik 1988), Ross Island's Cape Crozier, Beaufort Island, or of one individual captured 140 km north of Cape Bird (Emison 1968). Due to digestion rates of stomach contents, these two studies could only sample food eaten within a short travelling time of the rookery. Digestion rates for Adélie Penguins are not available, but experiments on Yellow-eyed Penguins (*Megadyptes antipodes*) show that most stomach contents are digested within 24 hours (van Heezik, pers. comm.).

Limited plankton sampling indicates that the distribution of *E. superba* stocks coincide with the outer edge of the continental shelf, the nearest stocks to Cape Bird being 400-500 km away (Marr 1962). Perhaps it is energetically more efficient for the penguins to exploit the larger species of krill, even if they have to travel further. Might this explain why Adélie Penguins travelled more than 100 km beyond the rookery during the long foraging trips of the incubation period?

Behaviour at sea

Trivelpiece *et al.* (1986) showed that, for Gentoo and Chinstrap Penguins, dives consisted of underwater swimming and feeding dives. Underwater swimming dives averaged 50 seconds with short pause times, 12 seconds, in between. By contrast, mean feeding dive times were 128 and 91 seconds for Gentoo and Chinstrap Penguins, respectively. Therefore, we have assumed in this study that consecutive dives lasting more than 60 seconds were feeding dives. Both the mean "feeding" dive time and maximum dive times for Adélie Penguins were intermediate between those recorded for the other two pygoscelid species (Trivelpiece *et al.* 1986). Adélie Penguins are intermediate in body size between the larger Gentoo and smaller Chinstrap Penguins (Stonehouse 1967), and so the results of this study fit with the hypothesis that diving ability is correlated positively with body size in penguins (Stonehouse 1967). The mean dive : pause ratio we observed for Adélie Penguins was the same as the mean dive : pause ratio reported for Chinstrap Penguins (2.6) and less than that for Gentoos (3.4) (Trivelpiece *et al.* 1986). However, dive : pause ratios were affected by the length of the dives, longer dives requiring longer recovery periods. In fact, three of the four Adélie Penguins had dive : pause ratios greater than any reported for Chinstrap Penguins, and one was greater than any reported for Gentoo Penguins (Trivelpiece *et al.* 1986). This lends further support to the suggestion that Adélies are intermediate in diving ability between Chinstraps and Gentoos, and that body size is a major factor influencing diving ability.

Use of radio telemetry

The present system could be improved by means of stronger transmitters, a much longer baseline, and the receiving antennae being at higher elevations. In Antarctica, where suitable locations for tracking towers are not readily available, the best option may be satellite telemetry. The effect, if any, of wearing transmitters on the penguins' behaviour and survival prospects needs to be studied. From this study, no direct effect is apparent because the mortality in the sample of radioed birds was within normal annual limits (Ainley *et al.* 1983).

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A preliminary note on the radio telemetry technique used in this study was published in the bulletin *New Zealand Antarctic Record,* 1986, vol. 7, no. 2, pp. 14-18. The purpose of that report was to advertise the technique from a technical perspective. By contrast, this paper deals with the behaviour of the penguins, using the complete and substantially different data set, analysed in a totally different way.

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SHORT NOTE

Diet of Adélie Penguins during the Incubation Period at Cape Bird, Ross Island, Antarctica

The food of the Adélie Penguin (*Pygoscelis adeliae*) has been examined at only a few localities — at Cape Crozier, Ross Island, Beaufort Island, and Franklin Island (Emison 1968), at Signy Island, South Orkney Islands (Lishman 1985, White & Conroy 1975) and at King George Island, South Shetland Islands (Volkman *et al.* 1980). Although euphausiids comprise the largest proportion of the diet by numbers and by weight at all localities sampled, on the islands of the Antarctic Peninsula *Euphausia superba* were taken, whereas at Cape Crozier, Beaufort Island and Franklin Island *E. crystallorophias* formed the bulk of the diet of parents feeding chicks.

Information on the diet of Adélies on Ross Island during the incubation period is scarce, although 10 of the 37 complete samples taken by Emison (1968) were obtained from incubating birds towards the end of the incubation period. Foraging trips during the incubation period can last up to 2 weeks or more; the female taking the first foraging trip after laying the eggs and, after 2 weeks, returning to relieve the male, which takes the second foraging trip. In this study I collected stomach contents from Adélie Penguins returning from the first and second foraging trips during the incubation period.

At Cape Bird, Ross Island, over a period of 3 weeks (18 November-8 December 1985), I captured penguins as they returned to the rookery from a foraging trip. I collected the stomach contents from 16 birds by the water off-loading technique (Wilson 1984).

Two flushes were adequate to empty the stomach of its contents. I then shook each regurgitation until it was homogeneous and removed a 500 mL sample. I identified euphausiids from Emison's (1968) description, counted euphausiid eyes in each sample and calculated the total number of euphausiids in the stomach content by measuring the total volume of fluid. The entire regurgitation was sorted for amphipods, fish otoliths and any other remains.

Of the 16 stomach contents, 14 contained euphausiids, *E. crystallorophias* comprising 77.8-100% (average 97.3%) of the total number of prey items (Table 1). Amphipods were present in low numbers in 12 out of the 16 stomach contents, including two stomachs in which they were the only prey organisms present. *E. crystallorophias*, then, comprised on average 85% of the total number of prey items from all 16 stomachs. Numbers of *E. crystallorophias* varied from 276 to 41 938 per stomach, although in only one case did numbers exceed 4500. Lengths ranged 21-29 mm, indicating that adult *E. crystallorophias* were being ingested.

TABLE 1 — Composition of stomach contents from 16 Adélie Penguins during the incubation period.

(1985)	*E. crystallorophias*	% *E. crystallorophias*	Amphipod Species 1	Amphipod Species 2	Fish otoliths	Decapods	*E. superba*
18-11	285	100	-	-	-	-	-
18-11	-	-	-	35	-	-	-
20-11	1030	94.3	-	63	-	-	-
20-11	815	99.9	1	-	-	-	-
21-11	1420	99.8	-	1	-	2	-
22-11	577	100	-	-	-	-	-
22-11	563	100	-	-	-	-	-
25-11	565	100	-	-	-	-	-
25-11	4490	99.6	18	2	-	-	-
29-11	1012	99.5	5	-	-	-	-
29-11	41938	99.9	9	9	-	-	1
1-12	-	-	20	-	-	-	-
1-12	480	95.4	23	-	-	-	-
4-12	1827	97.4	42	5	-	-	2
7-12	973	77.8	3	275	-	-	-
8-12	276	97.9	6	-	1	-	-

In the 10 stomachs that Emison (1968) collected from incubating birds in the first two weeks of December, an average of 1389 food organisms were found, of which about 95% can be assumed to have been euphausiids because Emison lumped these samples together with others collected during that time from chick-feeding birds. In my study, if the stomach containing 41 938 prey items is excluded, the remaining 15 stomachs contained a mean of 988 ± 1067 prey items. This value is similar to Emison's, although in my study more stomachs containing very low numbers of prey items were found and euphausiids comprised a slightly smaller proportion of the total number of prey items taken. While Emison found that fish made up a portion of his samples, only one fish otolith was recovered in this study. This could indicate a different feeding range or increased availability of fish later in the season. It could also be a consequence of sampling from a slightly different location on Ross Island. Two crabs and three *E. superba* were also found.

The maximum count of 41 938 individuals per stomach far exceeds Emison's maximum value of 12 500 from one stomach and his average value of 5300 food items from 37 samples, and it may have have been the result of several days of feeding. However, if length-weight equations calculated for *E. superba* (Lockyer 1973) are applied to *E. crystallorophias* to gain an approximation of the weight of food that such a large number of individuals would represent, then 42 000 individuals of an average length of 25 mm, assuming a 50:50 ratio of males to females, would amount to about 3800 g of krill. This is not an impossibly large value and may be the result of no more than two days of foraging. Digestion rates of euphausiids have not yet been determined in penguins, and so it is impossible to calculate how many days of feeding so many pairs of eyes would represent, but observations made on the digestion of fish in the Yellow-eyed Penguin indicate that all hard parts are digested within 24 hours of ingestion (pers. obs.).

The marked preponderance of *E. crystallorophias* in the diet, with occasional *E. superba* and some amphipods, is very similar to the diet during the chick-feeding period described by Emison (1968) at Cape Crozier, Beaufort Island, and from one sample collected from Franklin Island. He found that at Cape Crozier 94.6% and 91.5% of the diet, numerically, was made up of euphausiids (>99% *E. crystallorophias* and <1% *E. superba*) in the 1964-65 and the 1965-66 seasons respectively. *E. crystallorophias* has been described by Marr (1962) as occurring almost exclusively in the shelf water of the Ross Sea region, which is cold to the bottom. The absence of *E. superba* from the greater part of the shelf water was attributed by Marr to the failure of the warm deep current carrying *E. superba* larvae to penetrate more than a short distance on to the shelf.

The results of the radio-tracking study on Adélie Penguins carried out at the same time as the stomach sampling at Cape Bird (Davis *et al.*, this issue) indicate that birds were travelling long distances while on foraging trips during the incubation period, i.e. at least 100 km. The contents of the stomachs collected in this study probably represented only what had been ingested within 24-48 hours before capture. However, with the large distances covered during 2-week long foraging trips, the penguins could possibly take other foods or, alternatively, similar prey but in different proportions, during a large part of the foraging trip.

The results from this study show that *E. crystallorophias* is at least an important food item in the diet of Adélie Penguins foraging within a few days of travelling and foraging from Cape Bird during the incubation period. They provide further evidence that the diet of Adélie Penguins in the Ross Sea region may be fundamentally different from that of penguins on the Antarctic Peninsula in terms of the species of euphausiids they feed on.

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WETLAND WILDLIFE TRACKS

Wetlands are a dwindling resource because of natural infilling and infilling by man by induced erosion or reclamation. They may also be wholly or partly ruined as wildlife habitat by uncontrolled grazing.

Many well-meaning landowners and managers know too little of the wildlife that inhabits their wetlands, of the significance of this wildlife and of how to protect the wetlands. They may not realise how grazing may damage the habitats. The ones that do may fence a wetland or have this done with assistance from a trust.

Even if a landowner does make a wetland secure, vermin, such as rats, feral and domestic cats, possums, weasels, stoats and even hedgehogs may make the wetland precarious for birds. Yet, the vermin may escape attention because of nocturnal habits. The number of vermin may be so high that the time, effort and money spent on preservation of the birds can be wasted.

A first need for assessing a wetland's wildlife value is to find out what animals are present

Ducks, gulls, shags, stilts, herons, swan, geese and harrier are normally easy to detect by sight or sound. Other animals, being furtive or nocturnal, and inhabiting dense wetland vegetation, are often hard or impossible to detect. Examples are the Banded Rail, Spotless Crake, Bittern, vermin and sometimes the Pukeko.

TRACKS AS A SURVEY TOOL

Animals can be detected with certainty from their tracks. Footprints can be deep and clear in soft, litter-free mud. Where the mud has firmed, where a foot is put down unevenly or where a track is distorted by litter, partial tracks are formed. Nevertheless, after some experience in track reading, one can use partial tracks as reliably as complete ones.

Within limits, tracks can give information on birds' breeding, density and behaviour and on the presence and habits of vermin. Breeding is shown by the miniature tracks of juvenile birds beside those of adults. By reading tracks, one can learn much of wetland wildlife.

The illustrations of the footprints presented (correlated with sightings) help distinguish the tracks of one animal from those of others (see Figures 1-12). The study was confined to the tracks of common birds and other animals in 14 wetlands on either side of the Inlet road, running east from Keri Keri, parallel to the Keri Keri Inlet, in the Bay of Islands, Northland.

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FIGURE 1 — For long film exposure a special stand was used to position the lens 450 mm above the ground surface.

FIGURE 2 — **Banded Rail** *(Rallus philippensis):* Observed length of central toe 30-40 mm; ratio between length of central and outer toes 1:3; angle between central and outer toes 25-60°. The last indicates that the bird can vary the placement of the outer toes.

Tracks are typically encountered along the margins of major channels in mangrove forest, where mud crabs under large trees are common.

Tracks have been encountered in all of the 14 sites examined, including mud under open stands of manuka *(Leptospermum scoparium).* The wide dis-persal of the tracks is related to the relatively large distances this bird travels overland and to its occasional movement by night from one wetland to another.

No tracks were encountered in the dense rush stands upstream from the mangrove or in dense thickets that mark fernbird habitats.

FIGURE 3 — ***Spotless Crake*** *(Porzana tabuensis plumbea)*: Observed length of central toe 40 mm; ratio between length of central and outer toes 1:2; angle between the central and outer toes 40-50°.

But for one landowner, none knew that this bird inhabited their wetlands. Yet, even though they were not numerous, their tracks were encountered in 13 out of 14 wetland sites examined, given that the stubby tracks with imprint of the back toe can give clear identification.

Even when, from fresh tracks, we knew this bird to be nearby, only once did we get a response to its call from a tape.

FIGURE 4 — ***White-faced Heron*** *(Ardea novaehollandiae)*: Observed length of central toe 50-60 mm; ratio between length of central and outer toes 1:1; angle between the central and outer toes 40-50°.

Coming down from their roosts or nests in trees, they frequent wetlands to feed. Like the bittern, they stride through swamp and along channel margins spearing and swallowing frogs and gambusia (introduced so-called mosquito fish), indicating considerable storage capacity. This accounts for periods of absence from wetlands. Their tracks, however, betray their periodical visits.

FIGURE 5 — ***Pied Stilt** (Himantopus himantopus leucocephalus)*: Observed length of central toe 40 mm; ratio between length of central and outer toes 1:2; angle between the central and outer toes 40-60°.

The Pied Stilt is a social bird. Numerous tracks of it in a helter-skelter pattern at a given site indicate that these are from several birds.

The Banded Rail, on the other hand, tends to be solitary, although when with young it can move in a family group. If one encounters numerous tracks of it at a given site, they are likely made by a single Banded Rail and one can follow the direction in which it has moved.

Moreover, according to our observations, the footprint of the stilt always shows a rather wide angle between the central and outer toes, whereas that of the Banded Rail shows variable angles.

FIGURE 6 — ***Ducks***: Observed length of central toe 50-60 mm; ratio between length of central and outer toes 1:2; angle between the central and outer toes 25-40°. *Specific ducks may give figures deviating from these.*

But for the rounding of the outer toes towards the centre, duck tracks can closely resemble those of Pheasant. In soft mud, the imprint of the web between the toes eliminates Pheasant.

No ducks were observed in the densely vegetated wetland that marks the fernbird habitat. In mangroves they were observed to breed far upstream only, where there is enough fresh water for water weeds to develop. Once the young develop, they move farther downstream. More importantly, the mangrove channels provide roosting places for ducks, but in a periodic and localised manner.

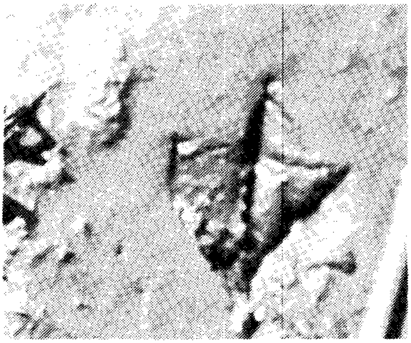

FIGURE 7 — Webbing between toes in duck track

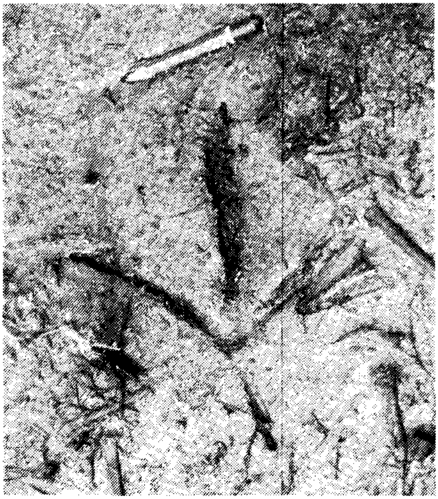

FIGURE 8 — ***Australasian Bittern*** *(Botaurus stellaris poiciloptilus)*: Observed length of central toe 80 - 90 mm; ratio between length of central and outer toes 1:3; angle between the central and outer toes 40-50°.

The length of the central toe is the key to identification, compared with the track of the White-faced Heron. In addition, the length of the central toe in relation to that of the outer toes in the bittern track is greater than in the heron track. Moreover, the imprint by a bittern foot is deeper than that by a heron foot.

Even though it was breeding at 3 or 4 sites only, its tracks revealed that it regularly visited all the 14 wetland sites examined, as we knew also from sightings.

The male, slightly sturdier than the female, seemed more mobile. During the breeding season it boomed from time to time from unlikely breeding sites, presumably trying to attract a female.

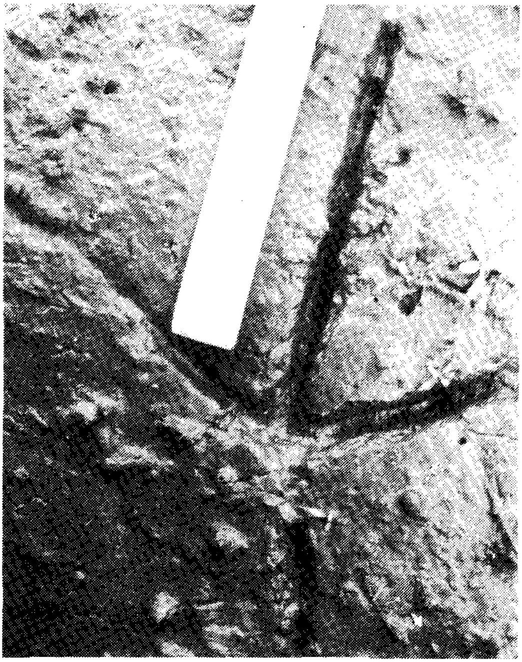

FIGURE 9 — **Pukeko** *(Porphyrio porphyrio melanotus)*: Observed length of central toe 95-110 mm; ratio between length of central and outer toes 1:0-1:2; angle between the central and outer toes 55°.

Even though the Pukeko is not an inconspicuous bird, it can stay hidden, particularly during mid-summer days.

An incomplete Pukeko presence was obtained where dense vegetation extended well beyond the border of a wetland.

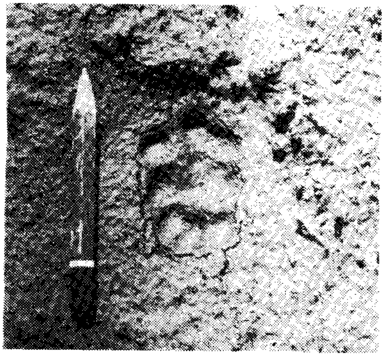

FIGURE 10 — ***Cats*** *(feral and domestic)*: Observed width 30 mm, length 37 mm. Owing to the range in size and in behaviour of this animal, imprints of cat paws in mud are quite variable. However, all show a multiple "cushion" imprint, similar to that shown in Figure 10.

Although less numerous, cats had a similar distribution to possums.

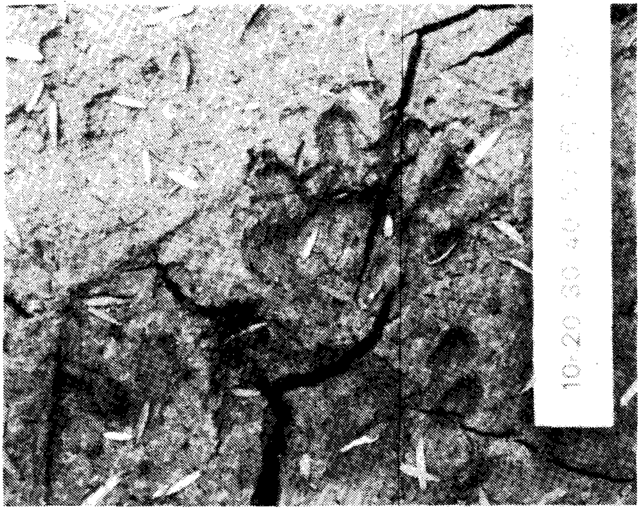

FIGURE 11 — ***Brush-tailed Possum** (Trichurus vulpecula)*: Observed width 45 mm, length 39 mm. The possum track in mud is rather variable, depending on how the animal splays its feet when walking on a soft substratum. To check on this, we made footprints in mud with an artificially splayed foot of a possum that had just been killed by traffic. The pattern obtained was like that in Figure 11. Numerous tracks were observed at the margins of or within all examined wetlands, other than mangrove.

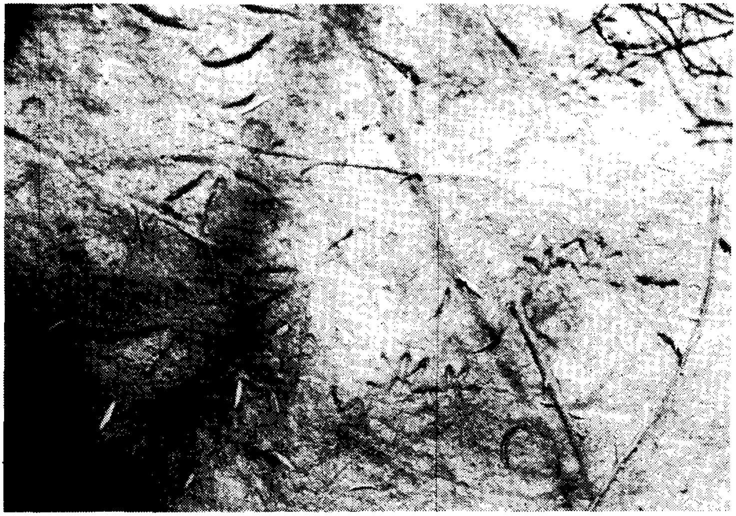

FIGURE 12 — ***Rat** (Rattus norvegicus)*: Rat tracks are shown alongside those of juvenile Banded Rail and an old imprint of a possum foot. Rats were common in all examined wetlands, except in the dense rush stands upstream from mangrove. Within mangrove they seem to follow the receding tide, suggesting that they travel long distances.

OSTEOLOGICAL DIFFERENCES BETWEEN *SULA* AND *MORUS*, AND A DESCRIPTION OF AN EXTINCT NEW SPECIES OF *SULA* FROM LORD HOWE AND NORFOLK ISLANDS, TASMAN SEA

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ABSTRACT

Osteological differences between boobies, *Sula*, and gannets, *Morus*, were found for every major element examined. These differences confirm that *Sula* and *Morus* are generically distinct.

Sula tasmani n.sp. is described from bones found in aeolian coral sand dunes at Lord Howe and Norfolk Islands, Tasman Sea. *Sula tasmani* is larger than extant and known fossil species of *Sula*, the upper part of its massive bill being more concave laterally.

INTRODUCTION AND METHODS

At Lord Howe and Norfolk Islands, Tasman Sea, bones were found *in situ* and as float of two species of booby (*Sula*). The bones were determined as being of the Masked Booby (*S. dactylatra*), which still breeds there, and of a similar but larger booby, which we shall call the Tasman Booby. The Tasman Booby is described in this paper as a new extinct species. The bones were collected from aeolian coral sand, at Lord Howe Island from a storm-eroded cliff at Middle Beach and from sand used for airport construction and at Norfolk Island from storm-eroded beaches and a sand quarry at Emily and Cemetery Bays (van Tets *et al.* 1981, 1984; Rich & van Tets 1982, 1984; and Rich *et al.* 1983).

The bones of the Tasman Booby were compared with those of all extant species of Sulidae and with descriptions of those of fossil Sulidae. Comparative material came from the collections of the Australian Museum, Sydney (AM); the Australian National Wildlife Collection, CSIRO Division of Wildlife and Rangelands Research, Canberra (ANWC); the British Museum (Natural History), Tring (BM); the Monash University Department of Earth Sciences (MU); the Museum of Victoria, Melbourne (MV); the National Museum of New Zealand, Wellington (NMNZ); and the University of Michigan Museum of Zoology, Ann Arbor (UMMZ).

Bones that lack the hard, smooth texture and the detailed sculpturing of fully formed bones are called juvenile and are considered to be of young birds close to fledging, but not chicks or fully grown birds.

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COMPARISON OF THE OSTEOLOGY OF *SULA* AND *MORUS*

At least from the time Linnaeus (1758) placed the boobies in *Pelecanus piscator* and the gannets in *P. bassanus*, there has been debate about the taxonomic distinctions between boobies and gannets. The New Zealand checklist (Kinsky 1970, 1980), the World checklist 2nd Ed. (Dorst & Mougin 1979), as well as Voous (1973), Cramp & Simmons (1977), Nelson (1978) and Harrison (1983), considered boobies and gannets to be congeneric, while the Australian checklist (Condon 1975), the World checklist 1st Ed. (Peters 1931), as well as Serventy *et al.* (1971) and Olson (1985), restricted the boobies to the genus *Sula* Brisson 1760 and placed the gannets in the genus *Morus* Vieillot 1816.

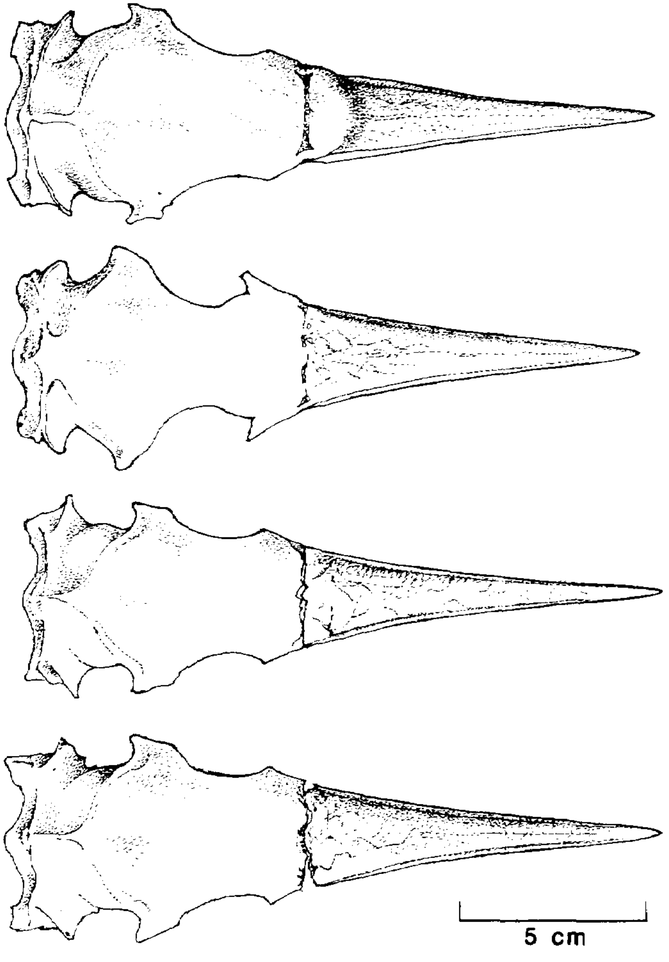

FIGURE 1 — Dorsal view of the skulls from top to bottom of *Morus serrator* ANWC BS2931, *Sula abbotti* ANWC BS1934, *S. dactylatra* ANWC BS2932 and *S. tasmani* n.sp. ANWC BS3322

The differences between *Sula* and *Morus* were based on external features (Ogilvie-Grant 1898, Mathews 1913, Mathews & Iredale 1921, Wetmore 1926, Berlioz 1950, von Boetticher 1957, Palmer 1962, Serventy *et al.* 1971) and can also be made from comparisons of signal patterns (van Tets 1965) and from skeletal morphology as described below.

Skull

In *Sula* the surface of the maxilla is rough all over the portions covered by horny plates. In *Morus* it is also rough except for an area directly in front of the naso-frontal hinge (Figures 1 and 2) where the top of the bill at its base is covered by skin and feathers. Shufeldt (1888, 1902) noted this difference when comparing the maxilla of *Morus bassanus* with those of *Sula sula* (=*piscator*) and other species of Sulidae, presumably *S. nebouxii* (=*gossi*) and *S. leucogaster* (=*brewsteri*), as shown on his Plate XXIII, figures 10 and 11 (1902).

From a lateral view, the dorsal profile of the skull shows a dip in front of the naso-frontal hinge, where the surface is smooth, and a bulge behind the naso-frontal hinge (Figure 2) in *Morus*, whereas in *Sula* the

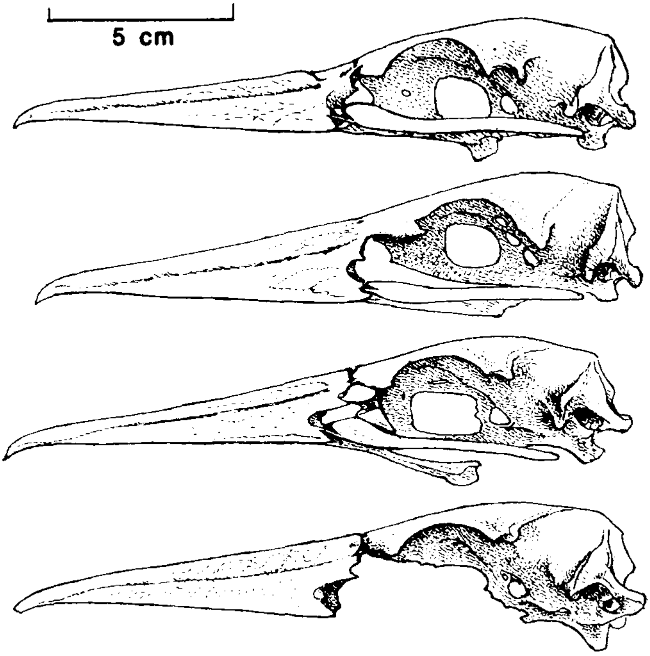

FIGURE 2 — Lateral view of the maxillae and crania from top to bottom of *Morus serrator* ANWC BS2931, *Sula abbotti* ANWC BS1934, *S. dactylatra* ANWC BS2932 and *S. tasmani* n.sp. ANWC BS3322

profile has a slight convex bulge in front of the naso-frontal hinge and a relatively straight slope behind the hinge and above the orbits.

Pectoral girdle

At the cranial end of the sternum there is a prominent ventral manubrial spine in *Morus*, but not in *Sula*, as was noted by Shufeldt (1902). The furcular facet on the carinal apex is from a lateral view deeply concave (Figure 3) in *Morus* and varies in *Sula* from slightly concave to slightly convex. The ventral edge of the carina is relatively narrower in *Morus* than in *Sula* (Figure 4).

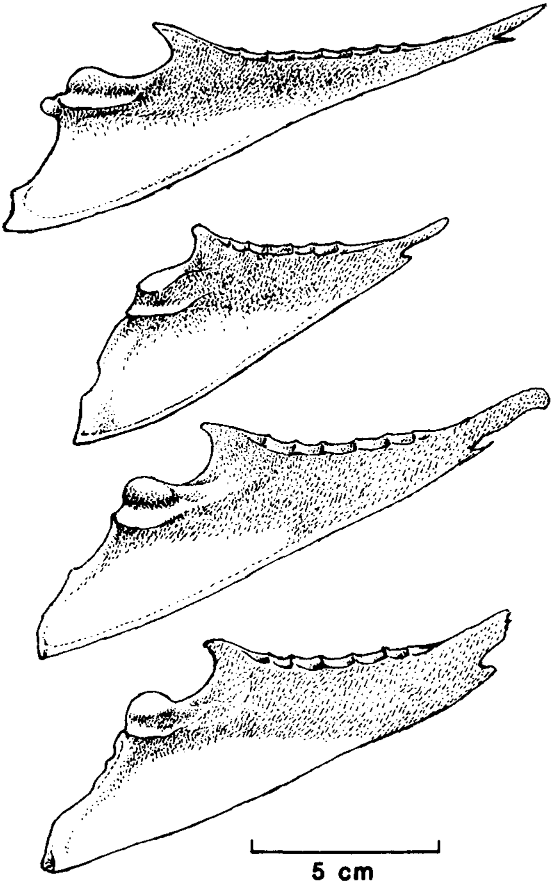

FIGURE 3 — Lateral view of the sterna from top to bottom of *Morus serrator* ANWC BS2931, *Sula abbotti* ANWC BS4374, *S. dactylatra* ANWC BS2932 and *S. tasmani* n.sp. ANWC BS3322

The sternal facet at the symphysis of the furcula is relatively narrower and deeper in *Morus* than in *Sula*. The clavicular shafts are relatively thicker in *Morus* than in *Sula*. There are usually one or more pneumatic foraminae between the coracoidal facet and the scapular tuberosity in *Morus*, but not in *Sula*.

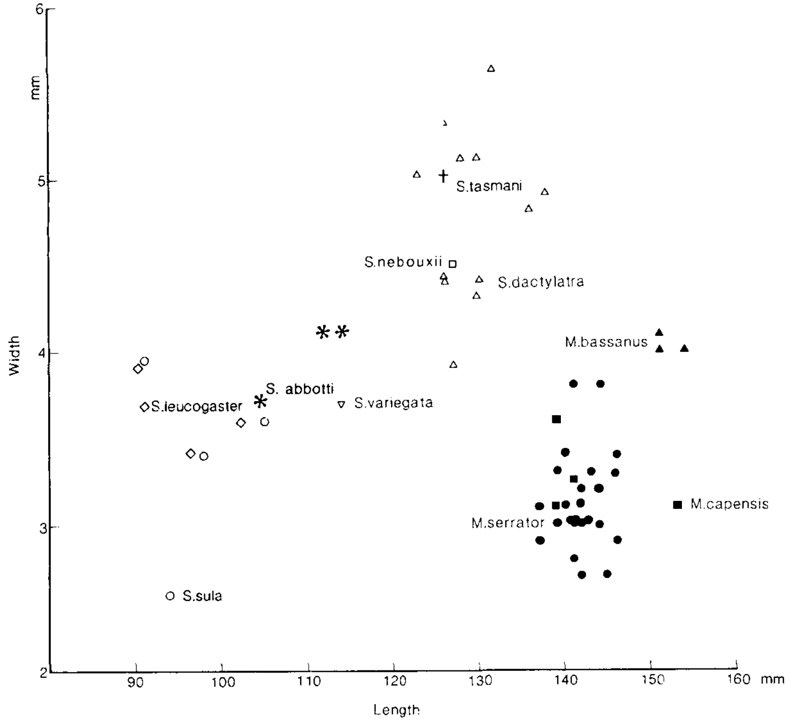

FIGURE 4 — Comparison of carinal widths and lengths in *Morus* and *Sula*. Measured were the length and greatest width of the carinal edge

On the scapula, at the anterior base of the acromion, is a pneumatic foramen on the dorsal side in *Morus* and on the ventral side in *Sula*. The distal end of the blade is less angular with respect to the shaft in *Morus* than in *Sula*.

Above the anterior sternal face of the coracoid, as noted by Wetmore (1926) and Brodkorb (1955), is a bulge in *Sula* and not in *Morus* (Figure 5). On the bulge is the anterior intermuscular line of Fisher (1945). Where the line terminates at the sternal facet is a prominent tubercle in *Sula* and not in *Morus*. The line ends at the sternal facet also more laterally in *Morus* than in *Sula*. Howard (1936) reported that the anterior sternal facet is relatively longer and narrower in *Morus* than in *Sula*, that the dorsal end is relatively broader in *Morus* than in *Sula*, and that the bicipital attachment is small and faintly marked in *Morus* but is a large and prominent pit in *Sula*. From a dorsal view, the furrow between the bicipital attachment and the glenoid facet is relatively broader in *Morus* than in *Sula*. The sterno-coracoidal process is pointed in *Morus* and truncated in *Sula* (Figure 5).

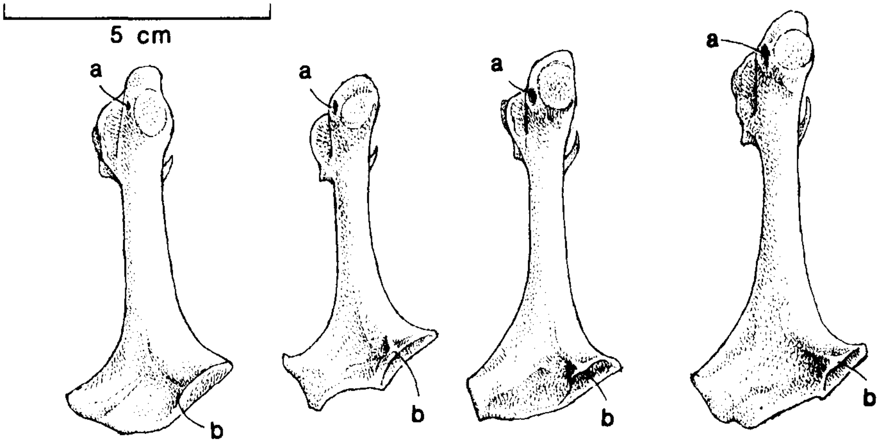

FIGURE 5 — Anterior view of the right coracoids from left to right of *Morus serrator* ANWC BS2931, *Sula abbotti* ANWC BS4374, *S. dactylatra* ANWC BS2932 and *S. tasmani* n.sp. MV164185. a = bicipital attachment, b = ventral end of anterior intermuscular line

Wing

The humerus is longer than the ulna in *Morus* and shorter than the ulna in *Sula*, including *S. abbotti*, where the humerus is almost as long as the ulna (Figure 6, Shufeldt 1902, Miller 1935, Howard 1958, Bourne 1976). The median crest of the humerus extends further distally in *Morus* than in *Sula* (Figure 7) and on the anconal or ulnar side, as indicated by Howard (1958), the central ridge is rounded and indistinct in *Morus* but is angular in *Sula*. At the distal end, *Morus* has a shallower impression for M. brachialis anticus than *Sula*. On the internal side of the olecranal fossa, *Morus* lacks the overhang with a few foramina under it (Wetmore 1930) that is indistinct in *Sula abbotti* and prominent in other *Sula*. The shapes of the external (= radial) condyle and the attachment for M. pronator brevis are too variable for us to confirm any of the differences between *Morus* and *Sula* that were suggested by Wetmore (1926, 1930, 1938).

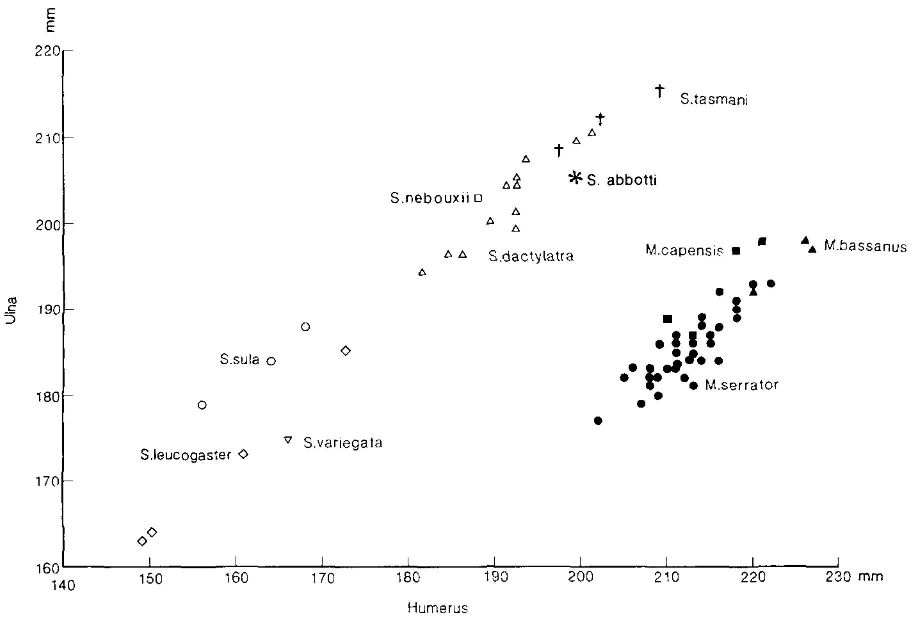

FIGURE 6 — Comparison of humeral and ulnar lengths in *Morus* and *Sula*

There is a foramen in the proximal radial depression of the ulna in *Sula* but not in *Morus* (Figure 8). The impression of M. brachialis anticus is relatively longer in *Morus* than in *Sula*. The shaft of the ulna is relatively thicker in *Morus* than in *Sula*. Relative to the internal and external condyles at the distal end of the ulna, the tip of the carpal tuberosity is more distal in *Sula* than in *Morus*.

At the distal end of the radius on the palmar side, relative to the scapho-lunar facet, a prominent foramen is more proximally located in *Morus* than one or more smaller foramina in *Sula*.

At the proximal end of the carpometacarpus, the pneumatic foramen in the internal ligamental fossa is much larger in *Morus* than in *Sula*, and the anterior carpal fossa has a prominent foramen in *Sula* and not in *Morus*. In *Sula* a ridge extends from the external ligamental attachment almost to the proximal end of metacarpal III. *Morus* does not have this ridge. In *Sula* the groove of the carpal trochlea extends farther on to the proximal end of metacarpal III than in *Morus*. We did not find any significant differences in the shapes of the pollical facet between *Morus* and *Sula*, as was suggested by Brodkorb (1963b).

Pelvic girdle

On the synsacrum, the anterior articular facet of the centrum is in *Morus* as deep as or deeper than it is wide, and in *Sula* it is as wide as or wider than it is deep.

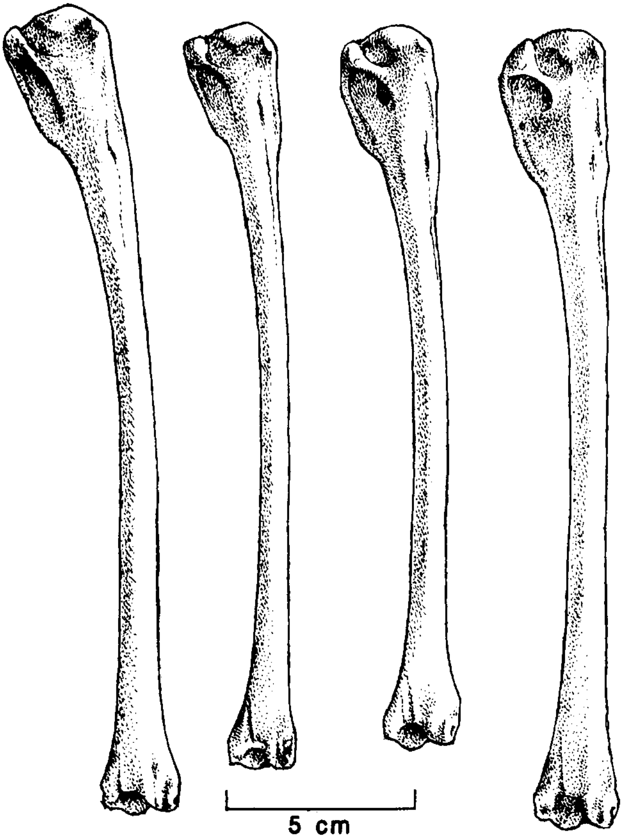

FIGURE 7 — Anconal views of the right humeri from left to right of *Morus serrator* ANWC BS2931, *Sula abbotti* ANWC BS4374, *S. dactylatra* ANWC BS2932 and *S. tasmani* n.sp. ANWC BS3329

The caudal part of the ilium is relatively broader above and behind the ilio-ischiatic fenestra in *Sula* than in *Morus*. The ilial process on the caudal edge of the pelvis is small and knoblike in *Morus* and in *Sula abbotti*, and it is large and pointed in other *Sula*.

Leg

The femur of *Morus* is longer with a relatively thinner shaft than that of *Sula*. At the proximal end, the junction of the trochanter and the trochanteric ridge is more angular in *Sula* than in *Morus*. The distal end is relatively broader in *Sula* than in *Morus*.

The tibiotarsus of *Morus* is longer, with a relatively thinner shaft, than that of *Sula*. The proximal and distal ends are relatively wider in *Sula* than in *Morus*. At the proximal end, the inner cnemial crest in *Morus*

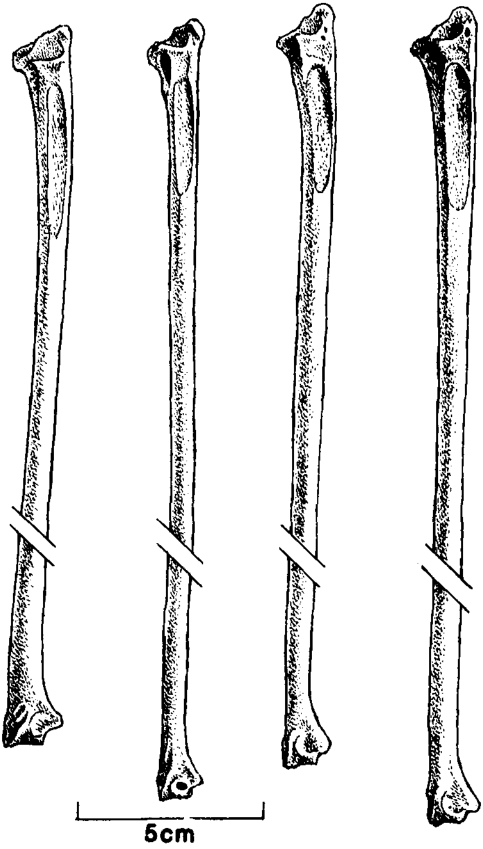

FIGURE 8 — Palmar view of proximal part and dorsal view of distal part of the right ulnae from left to right of *Morus serrator* ANWC BS2931, *Sula abbotti* ANWC BS4374, *S. dactylatra* ANWC BS2932 and *S. tasmani* n.sp. ANWC BS3329

is hooked at the distal end and in *Sula* not hooked. At the distal end, the anterior intercondylar fossa and the posterior intercondylar sulcus are relatively wider in *Sula* than in *Morus.*

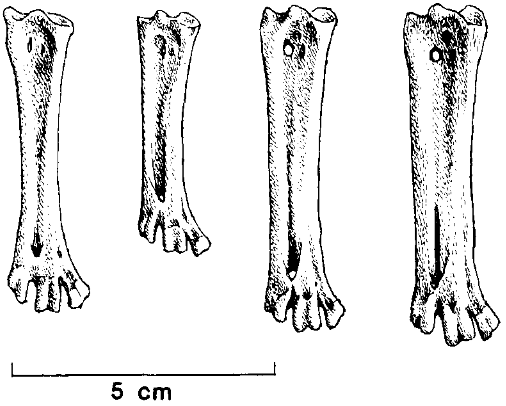

FIGURE 9 — Anterior view of the right tarsometatarsi from left to right of *Morus serrator* ANWC BS2931, *Sula abbotti* ANWC BS4374, *S. dactylatra* ANWC BS2932 and *S. tasmani* n.sp. ANWC BS3336

The tarsometatarsus of *Sula* has a relatively wider shaft than that of *Morus* (Figures 9 and 10). The proximal end of the tarsometatarsus is relatively wider in *Sula* than in *Morus.* The intercotylar prominence is more pronounced in *Sula* than in *Morus.* At the proximal end of the tarsometatarsus, as noted by Harrison (1978 Figure 2), there are differences between *Morus* and *Sula* in the arrangements of the calcaneal ridges and tendinal canals of the hypotarsus. *Morus* and *Sula* have three calcaneal ridges and three canal positions. *Morus* has a closed canal between a large inner ridge and a middle ridge and another closed canal between the middle ridge and an outer ridge. In *Sula abbotti* these two canals are open. In the other extant species of *Sula,* the outer and middle ridges are fused without a canal between them, a closed canal is between the middle and the inner ridges and, as described by Harrison (1978), a single large canal pierces the inner ridge. The inner ridge is not pierced by a canal in *Morus* and *Sula abbotti.*

The second phalanx of digit III is shorter than the first in *Morus* and longer than the first in *Sula.*

The aim of the osteological comparisons reported above was to determine whether the sulid bones found on Lord Howe and Norfolk Islands could be identified initially as either *Sula* or *Morus.* Besides verifying published differences, we found more characters that may be used to distinguish bones of *Morus* from those of *Sula.* These characters strengthen the case for maintaining *Morus* as a distinct genus.

Osteologically *S. abbotti* has most of the characters that separate *Sula* from *Morus*. *S. abbotti* differs from other extant species of *Sula* in having a *Morus*-like ilial process on the pelvis and a unique pattern of hypotarsal canals and ridges. Whether these and other morphological differences merit a new generic or subgeneric name for *S. abbotti* will have to await further study.

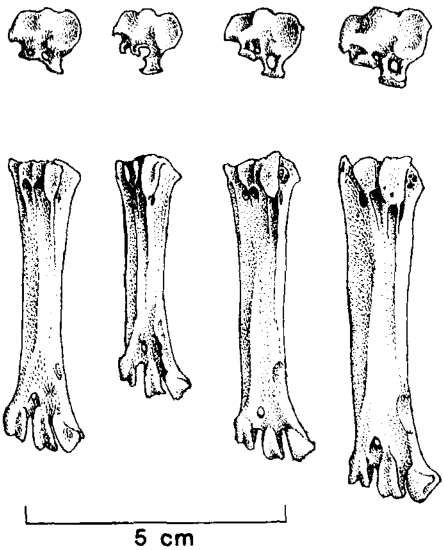

FIGURE 10 — Proximal and posterior views of the left tarsometatarsi from left to right of *Morus serrator* ANWC BS2918, *Sula abbotti* ANWC BS4374, *S. dactylatra* ANWC BS1198 and *S. tasmani* n.sp. MV 164124

SYSTEMATICS

Because the Tasman Booby differs in size and shape from modern and fossil species in the genus *Sula*, we propose for it the following new specific name:

Sula tasmani n.sp.

Holotype: ANWC BS3322, part skeleton, including all or parts of the following elements: maxilla, cranium, mandible, quadrate, cervical and thoracic vertebrae, sternum, ulna and carpometacarpus. Sand dunes near Kingston, Norfolk Island.

Paratypes: ANWC BS3318, part skeleton of a juvenile, including all or parts of the following elements: maxilla, cranium, mandible, quadrate, cervical and thoracic vertebrae, ribs, sternum, pelvis, coracoid, scapula, humerus, radius, ulna, carpometacarpus, wing phalanges, femur, tibiotarsus, fibula, tarsometatarsus, and pedal phalanges; ANWC BS3326, part skeleton of a juvenile, including all or parts of: mandible, cervical vertebrae, ribs, sternum, coracoid, scapula, humerus, radius, ulna, femur, tibiotarsus, fibula, tarsometatarsus and pedal phalanges. Sand dunes near Kingston, Norfolk Island.

Referred specimens: Skeletal elements listed in Table 9.

Etymology: Named after the Tasman Sea in which Norfolk and Lord Howe Islands are situated, and in honour of Abel Janszoon Tasman, who in 1642 sailed across the sea from Tasmania to New Zealand and who may have seen the bird alive.

Diagnosis: Similar to *S. dactylatra* but with a body larger and a bill broader and deeper and more dorso-laterally concave.

DESCRIPTION

Skull

The maxilla of the Tasman Booby [4 specimens — ANWC BS3318 (juvenile), BS3322, BS3323 and BS3333] differs from that of *S. abbotti*, which is similar in length, by being narrower at the base, shallower subterminally, more concave on the sides above the lateral groove, broader at the tip, and in having the maxillo-jugal junction situated relatively less posteriorly (Figures 1 and 2). The maxilla differs from that of *S. dactylatra*, which is similar in length, by being broader at the base, deeper, and more concave on the sides above the lateral groove, and broader at the tip (Figures 1 and 2). It differs from those of the other four extant species of *Sula* by being much larger and by being broader at the tip.

The cranium of the Tasman Booby [6 specimens — ANWC BS3318 (juvenile), BS3322, BS3325 (juvenile), BS3333, MV 150802 (juvenile) and 150805] differs from that of *S. abbotti*, which is similar in length, by being broader except at the naso-frontal hinge, and by having the temporal fossae [=crotaphyte fossae of Shufeldt (1888, 1902) and crotaphyte depressions of Owre (1967)] much larger and meeting at a narrow ridge medially on top of the cranium. It differs from that of *S. dactylatra*, which is similar in length, by having larger temporal fossae. It differs from those of other extant species of *Sula* by being much larger and by having relatively large temporal fossae.

The mandible of the Tasman Booby [11 specimens — AM F56463, ANWC BS3318 (juvenile), BS3320, BS3322, BS3324, BS3326 (juvenile), BS3327, MV 150806, 150808, 163650 and 164118] differs from that of *S. abbotti*, which is similar in length and depth, by having a wider tip, narrower dentaries, wider surangulars, narrower posterior ends and a large foramen on the dorsal surface near the internal articular process. It differs from that of *S. dactylátra*, which is similar in length, by having a wider tip and deeper posterior ends and by being slightly longer between the articular facet and the coronoid process. It differs from those of the other extant species of *Sula* by being much larger and by having a broader tip.

Pectoral girdle

The sternum of the Tasman Booby [5 specimens — ANWC BS3318 (juvenile), BS3322, BS3326 (juvenile), MV 150802 and 150808] differs from that of *S. dactylatra*, which is similar in size, by having a broader carinal apex, anterior carinal margin and separation between the dorsal lips of the coracoidal sulci. It differs from those of the other five extant species of *Sula* by being much larger (Figure 3).

The furcula of the Tasman Booby [1 specimen — MV 150808] differs from that of *S. dactylatra*, which is similar in size, by having a broader sternal facet and deeper clavicles. It differs from those of the other extant species of *Sula* by being much larger.

The scapula of the Tasman Booby [4 specimens — ANWC BS3318 (juvenile), BS3326 (juvenile), MV 150806 and 150808] differs from that of *S. dactylatra* by being slightly longer with a relatively larger proximal end. It differs from those of the other extant species of *Sula* by being much larger.

The coracoid of the Tasman Booby [6 specimens — ANWC BS3318 (juvenile), BS3321, BS3326 (juvenile), MV 150803, 150806 and 164185] differs from that of *S. dactylatra* by being slightly larger with a relatively broader sterno-coracoidal process, except for ANWC BS3318 (juvenile), which is similar in size. It differs from those of the other extant species of *Sula* by being much larger (Figure 5).

Wing

The humerus of the Tasman Booby [8 specimens — ANWC BS3318 (juvenile), BS3321, BS3326 (juvenile), BS3329, BS3332, BS4298 (juvenile), BS4299, and MV 150806] differs from that of *S. abbotti* by being relatively thicker with much larger proximal and distal ends and more distally located attachments for M. latissimus dorsi. It differs from that of *S. dactylatra* by being larger, except in juveniles. It differs from those of the other extant species of *Sula* by being much larger (Figure 7).

The ulna of the Tasman Booby [8 specimens — ANWC BS3318 (juvenile), BS3322, BS3326 (juvenile), BS3329, BS3332, MV 150806, 150808 and 164123] differs from those of *S. abbotti*, *S. dactylatra* and *S. nebouxii*, which are similar in size, by being thicker. It differs from those of other extant species of *Sula* by being much longer (Figure 8). At the distal end of the ulna, the external condyle extends proximally, relatively less in *S. abbotti*, and relatively more in *S. nebouxii* and *S. variegata*, than in *S. sula*, *S. leucogaster*, *S. dactylatra* and the Tasman Booby.

The radius of the Tasman Booby [7 specimens — ANWC BS3318 (juvenile), BS3321, BS3326 (juvenile), BS3332, MV 150804, 150806 and 150808] differs from that of *S. abbotti*, which is similar in length, by being thicker and having a larger distal end. It differs from that of *S. nebouxii*, which is similar in length, by the shaft being relatively thicker proximally and relatively thinner distally. It differs from that of *S. dactylatra*, which is similar in size, by the bicipital tubercle extending relatively less distally and having a relatively larger muscle scar in the ulnar depression. It differs from those of the other extant species of *Sula* by being much larger.

The carpometacarpus of the Tasman Booby [5 specimens — ANWC BS3318 (juvenile), BS3322, MV 150804, 150808 and 164126] is similar to or larger than that of *S. dactylatra*. Those of the other extant species of *Sula* are smaller.

Pelvic girdle

The pelvis of the Tasman Booby [3 specimens — ANWC BS3318 (juvenile), BS3332 and MV 150802 (juvenile)] is similar in size to that of *S. dactylatra*. Those of the other extant species of *Sula* are smaller.

Leg

The femur of the Tasman Booby [6 specimens — ANWC BS3318 (juvenile), BS3326, BS3328 (juvenile), BS3337 (juvenile), MV 150806 and 164331] is similar to or larger than that of *S. dactylatra*. Those of the other extant species of *Sula* are smaller.

The tibiotarsus of the Tasman Booby [4 specimens ANWC BS3318 (juvenile), BS3326 (juvenile), MV 150802 and 150806] differs from that of *S. dactylatra* by being slightly to much longer, with relatively longer bases to the inner cnemial crests and relatively shorter bases to the outer cnemial crests. It differs from those of the other extant species of *Sula* by being much larger.

The tarsometatarsus of the Tasman Booby [9 specimens — ANWC BS3318 (juvenile), BS3326 (juvenile), BS3327, BS3336, MV 150801, 150806, 164124, 164137 and 164334] differs from that of *S. dactylatra* by being broader and slightly to much longer. It differs from those of the other extant species of *Sula* by being much larger and by having, as in *S. dactylatra*, a tubercle on the internal edge of the internal cotyla (Figures 9 and 10).

General

The bones of the extinct Tasman Booby of Lord Howe and Norfolk Islands have the characteristics of *Sula* as distinct from those of *Morus* as outlined above. In general proportions, shape and size, the bones of the Tasman Booby resemble most those of *Sula dactylatra* from Lord Howe and Norfolk Islands, but are more massive. *S. dactylatra* at these islands is much larger than in the Atlantic Ocean and at low latitude colonies in the Indian and Pacific Oceans. The bones of the Tasman Booby and of *S. dactylatra* from Lord Howe and Norfolk Islands are also larger than those of other species of *Sula*, except for the wing bones of *S. abbotti*, which has a smaller body and shorter legs (cf. Bourne 1976, Nelson 1978). Measurements of the bones of the Tasman Booby and *S. dactylatra* from Lord Howe and Norfolk Islands are given in Tables 1-8.

Of the fossil species of *Sula* listed by Brodkorb (1963a), *S. ronzoni* and *S. arvernensis* of the Oligocene of France are based on poorly preserved pelves and their taxonomic status is debatable (cf. Harrison 1975, Olson 1985). The remaining fossil species, *S. universitatis*, *S. pohli*, *S. willetti*, *S. guano*, *S. phosphata* and *S. humeralis*, are based on skeletal elements that are smaller than those of *S. dactylatra* and are therefore also smaller than those of the Tasman Booby (Bourne 1976, Brodkorb 1955, 1963b, Howard 1958, Miller 1925, 1935, Miller & Bowman 1958).

TABLE 1 — *Measurements (mm) of skulls of S. tasmani and S. dactylatra from* Norfolk and Lord Howe Islands

		S. tasmani		S. dactylatra
		Fully-grown	Juvenile	Modern
Length of maxilla	x	100	96	96
	range	98-102	-	90-100
	n	3	1	10
	sd	-	-	2.8
Width across naso-frontal hinge	x	26	25	24
	range	26-27	-	22-25
	n	3	1	10
	sd	-	-	0.9
Width at preorbital process	x	35	-	33
	range	35-36	-	31-35
	n	2	-	9
	sd	-	-	1.3
Width across opisthotics	x	44	43	41
	range	43-44	-	40-43
	n	2	1	10
	sd	-	-	0.9
Length of cranium	x	73	70	70
	range	72-73	-	66-74
	n	2	1	10
	sd	-	-	1.9
Depth of cranium	x	32	30	32
	range	31-32	-	28-33
	n	2	1	10
	sd	-	-	1.4
Depth of mandible at coronoid process	x	19	-	17
	range	18-20	18-19	15-18
	n	9	2	11
	sd	0.8	-	0.8
Width of mandible in front of coronoid process	x	5.3	5.1	4.6
	range	5.1-5.5	-	3.7-5.1
	n	9	2	11
	sd	0.2	-	0.4
Distance from coronoid to posterior process	x	37	35	33
	range	36-38	-	31-35
	n	7	1	10
	sd	0.6	-	1.3

TABLE 2 — Measurements (mm) of coracoids of *S. tasmani* and *S. dactylatra* from Norfolk and Lord Howe Islands

		S. tasmani		S. dactylatra
		Fully-grown	Juvenile	Modern
Greatest length	x	75	75	68
	range	-	-	67-73
	n	3	2	10
	sd	-	-	1.9
Length from head to internal distal angle	x	63	63	58
	range	63-65	62-64	55-61
	n	4	2	10
	sd	0.9	-	1.9
Ventral width	x	32	32	30
	range	-	-	28-31
	n	1	1	10
	sd	-	-	1.1
Length of sternal facet	x	31	31	28
	range	30-31	-	26-30
	n	2	1	10
	sd	-	-	1.1

TABLE 3 — Measurements (mm) of humeri of *S. tasmani* and *S. dactylatra* from Norfolk and Lord Howe Islands

		S. tasmani		S. dactylatra
		Fully-grown	Juvenile	Modern
Length	x	209	195	193
	range	206-210	192-199	186-202
	n	3	2	10
	sd	-	-	5.2
Proximal width	x	30	27	29
	range	-	-	28-30
	n	3	2	9
	sd	-	-	0.9
Shaft width at midpoint	x	11	10	8.3
	range	-	9-11	7.8-9.1
	n	3	3	10
	sd	-	-	0.5
Distal width	x	23	21	20
	range	21-23	20-22	19-21
	n	4	3	10
	sd	0.9	-	0.6

TABLE 4 — Measurements (mm) of ulnae of *S. tasmani* and *S. dactylatra* from Norfolk and Lord Howe Islands

		S. tasmani		*S. dactylatra*
		Fully-grown	Juvenile	Modern
Length	x	212	212	204
	range	208-216	207-217	196-211
	n	5	2	9
	sd	4.3	-	4.5
Proximal width	x	17	14	15
	range	16-18	-	14-15
	n	5	2	9
	sd	0.7	-	0.2
Minimum shaft width	x	8.3	7.5	7.4
	range	7.7-8.5	7.2-7.7	7.0-7.9
	n	6	2	9
	sd	0.4	-	0.3
Distal width	x	14	13	14
	range	14-15	13-14	13-15
	n	6	2	8
	sd	0.5	-	0.5

TABLE 5 — Measurements (mm) of carpometacarpi of *S. tasmani* and *S. dactylatra* from Norfolk and Lord Howe Islands

		S. tasmani		*S. dactylatra*
		Fully-grown	Juvenile	Modern
Length	x	92	90	86
	range	-	-	85-90
	n	2	1	9
	sd	-	-	1.8
Proximal width	x	20	18	18
	range	19-20	-	17-19
	n	2	1	9
	sd	-	-	0.7
Minimum shaft width	x	4.7	5.7	5.4
	range	4.6-4.7	-	4.7-5.7
	n	2	1	9
	sd	-	-	0.3
Distal width	x	11	11	11
	range	-	-	10-12
	n	2	1	9
	sd	-	-	0.5

TABLE 6 — Measurements (mm) of femora of *S. tasmani* and *S. dactylatra* from Norfolk and Lord Howe Islands

		S. tasmani		*S. dactylatra*
		Fully-grown	Juvenile	Modern
Length	x	68	66	64
	range	67-70	65-67	61-66
	n	3	3	10
	sd	-	-	1.7
Proximal width	x	15	15	14
	range	-	14-15	13-15
	n	3	3	10
	sd	-	-	0.4
Minimum shaft width	x	8.1	7.7	7.4
	range	8.0-8.2	7.4-7.9	6.6-7.8
	n	3	3	10
	sd	-	-	0.3
Distal width	x	15	15	14
	range	-	-	13-15
	n	3	3	10
	sd	-	-	0.6

TABLE 7 — Measurements (mm) of tibiotarsi of *S. tasmani* and *S. dactylatra* from Norfolk and Lord Howe Islands

		S. tasmani		*S. dactylatra*
		Fully-grown	Juvenile	Modern
Length	x	100	102	95
	range	-	101-102	95
	n	1	3	10
	sd	-	-	2.2
Proximal width	x	12	12	11
	range	-	12-13	11-12
	n	1	3	9
	sd	-	-	0.3
Minimum shaft width	x	8.0	8.3	7.3
	range	-	7.8-8.7	6.9-7.7
	n	1	3	10
	sd	-	-	0.3
Distal width	x	15	15	13
	range	-	-	13-14
	n	1	3	10
	sd	-	-	0.5
Distal depth	x	13	1412	
	range	-	13-14	11-13
	n	1	3	10
	sd	-	-	0.6

TABLE 8 — Measurements (mm) of tarsometatarsi of *S. tasmani* and *S. dactylatra* from Norfolk and Lord Howe Islands.

		S. tasmani		*S. dactylatra*
		Fully-grown	Juvenile	Modern
Length	x	64	63	60
	range	62-65	61-63	57-63
	n	6	3	10
	sd	0.8	-	1.4
Maximum proximal width	x	17	16	15
	range	-	15-16	14-16
	n	6	3	10
	sd	0.2	-	0.4
Minimum shaft width	x	11	10	10
	range	-	-	9-10
	n	6	3	10
	sd	0.1	-	0.5
Distal width	x	17	16	16
	range	-	15-16	15-16
	n	5	3	10
	sd	0.3	-	0.5

DISCUSSION

On Norfolk Island the bones of *Sula tasmani* n.sp. were found *in situ* with those of the kiore or Polynesian rat (*Rattus exulans*) and below charcoal with a radiocarbon date of about 800 years BP or 1200 AD (Meredith *et al.* 1985). The rat was presumably introduced by the Polynesians , who left stone artifacts on the island and introduced a plantain banana (*Musa* sp.) (King MS and Laing 1915). The Polynesians may have directly or indirectly caused the extinction of the Tasman Booby on Norfolk Island.

When Norfolk Island was discovered in 1774 (Hoare 1974) the only booby recorded by Cook, and painted by George Forster, was the Masked Booby (*Sula dactylatra*). King (MS) expressed annoyance that the Masked Booby did not nest on the main island but on relatively inaccessible Philip Island. He landed and settled near the location where the Tasman Booby material was found and reported that the area was so densely covered with scrub that a site had to be cleared to pitch his tents. The area, therefore, was too densely wooded for ground-nesting by boobies.

The extracts from journals and letters of the First Fleet quoted by Rabone (1959) make no mention of sulids at Lord Howe Island at the time of its discovery (15 Feburary 1788) and at the time of the first landing (13 March 1788) by Lieutenant Henry Lidgbird Ball and the crew of the *Supply*. When the *Supply* returned from Sydney with other ships on 16 May 1788, however, the most numerous birds at the same landing site on the sandy shores of the lagoon were "thousands of gannets", very large

TABLE 9 — *Bones from Norfolk (N) and Lord Howe (LH) Islands referred to Sula tasmani*

Museum Number		Elements	Location
AM	F56463	mandible	Middle Beach, LH
ANWC	BS3320	mandible	Cemetery bay, N
	BS3321	coracoid, humerus, radius	" " "
	BS3323	maxilla	" " "
	BS3324	mandible	" " "
	BS3325	cranium	" " "
	BS3327	mandible, tarsometatarsus	" " "
	BS3328	femur	Emily Bay "
	BS3329	humerus, ulna	Blinkey Beach, LH
	BS3332	humerus, ulna, synsacrum	" " "
	BS3333	craniaum, maxilla	" " "
	BS3336	tarsometatarsus	Cemetery Bay, N
	BS3337	femur	" " "
	BS4298	humerus	Blinkey Beach LH
	BS4299	humerus	" " "
MV	150801	tarsometatarsus	Nepean Island N
	150802	cranium, sternum, pelvis, tibiotarsus	Cemetery Bay, N
	150803	coracoid	" " "
	150804	radius, carpometacarpus	" " "
	150805	cranium	" " "
	150806	mandible, scapula, coracoid, humerus, ulna, radius, femur, tibiotarsus, tarsometatarsus	" " "
	150808	mandible, sternum, furculum, scapula, ulna, radius, carpometacarpus	" " "
	163650	mandible	" " "
	164118	mandible	" " "
	164123	ulna	" " "
	164124	tarsometatarsus	" " "
	164126	carpometacarpus	" " "
	164137	tarsometatarsus	" " "
	164185	coracoid	" " "
	164331	femur	" " "
	164334	tarsometatarsus	" " "

and fat. According to Lieutenant John Watts of the *Lady Penrhyn* (Anon 1789), they were in prodigious number, the "females" all being on their nests, which were simple hollows in the sand. Many "gannets" and their eggs were collected for food, but apparently none as scientific specimens. We have not located any drawings of them. It has been assumed that the "gannets" were the Masked Booby, although Hindwood (1940) noted that eggs in May was at variance with the present nesting time of *S. dactylatra* at Lord Howe Island, where breeding occurs from September to January, most eggs being laid in October (Hull 1910). At Philip Island near Norfolk Island, eggs are laid from 5 July to 3 January, with a peak in September (Hermes *et al.* 1986). The nests of *S. dactylatra* are relatively far apart for sulids, some clumping in small groups of a few nests (Nelson 1978). The Australasian Gannet (*Morus serrator*) does nest in very dense colonies, but it is smaller than the North Atlantic Gannet (*M. bassanus*) and its nesting season is similar to that of *S. dactylatra*, August to December in New Zealand (Oliver 1955) and October to January in Australia (North 1912, Mathews & Iredale 1921). At Philip Island eggs are laid from 30 August to 1 Feburary (Hermes *et al.* 1986).

Thus, the dense nesting with a peak of egg-laying in May by a very large fat "gannet" suggests a sulid other than *Sula dactylatra* and *Morus serrator*. The observations by the homeward-bound members of the First Fleet may have been the first, last and only recorded sightings of *Sula tasmani.*

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SHORT NOTE

Group Sizes of Red Shining Parrots on 'Eua, Kingdom of Tonga

In Fiji, parrots of the genus *Prosopeia* generally occur singly or in small groups of up to five individuals (Porter 1935, Brown & Child 1975, Holyoak 1979); but flocking of up to 40 birds, mostly in fruiting trees, has been reported (Bahr 1912, Wood & Wetmore 1926, Holyoak 1979, Clunie 1984).

During an 18 months field study of Red Shining Parrots (*Prosopeia tabuensis*) on the Tongan island of 'Eua, I made 380 observations of feeding parrots involving 735 birds. These observations are listed in Table 1. Mean group size (MGS, bottom line in Table 1) is lowest ($p < 0.01$) during the breeding season, which is from June to October, although a few pairs start breeding as early as May. The variation of MGS in different plant species apparently depends on the amount of food provided by a plant species: higher MGS (right-hand column in Table 1) occurs in trees which fruit prolifically, whereas in small trees, bushes and vines (*Melodinus vitiense* and many of the 'other species' in Table 1), parrots were most often seen feeding singly.

The data indicate that adult Red Shining Parrots live in pairs, being accompanied by their offspring after the breeding season (when MGS is higher than two). During the breeding season, when females spend most of the time on their nests, the frequency of observations of single birds increased. The data do not give information about the social behaviour of immature birds other than that they do not flock.

Non-feeding Red Shining Parrots have been seen in groups of one to eight birds; aggregations of more than four birds have been very rare. During the course of the study, M. Greenfield (pers. comm.) once saw a flock of more than 10 parrots feeding in guavas (*Psidium guajava*).

From the distribution of group sizes shown in Table 2, I conclude that no permanent associations of different families exist, 86.2% of the

TABLE 1 — Total numbers of individuals (large numerals)/numbers of observations (small numerals) per food species per month. The fruiting seasons of each species are stippled. MGS: mean group size.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Σ	MGS
Myristica	17/8	14/6	16/8	10/5	32/14	12/7	13/7	12/7	15/7	16/7	20/7	11/5	188/86	2.14
Psidium		21/8	19/8	19/8	21/8	8/4	19/8	12/5					119/49	2.43
Inocarpus	19/7	19/7	16/7	7/3	5/2								66/26	2.54
Calophyllum				9/4	21/11	15/8	5/3	5/3					55/29	1.90
Rhus		13/5	20/8	17/6									50/19	2.63
Elattostachys	11/5	10/5	9/4	6/3			3/1	3/2					42/20	2.10
Carica		5/3			4/2	4/2		3/2	5/3		4/2		25/14	1.79
Malisia									11/6	10/5			21/11	1.91
Pleigynium					7/3	6/4	3/2	3/2	2/1				21/12	1.75
Melodinus	4/3								4/3	3/2	2/2	6/4	19/14	1.36
Σ	51/23	82/34	80/35	68/29	90/40	45/25	43/21	38/21	37/20	29/14	26/11	17/9	606/282	2.15
other species	9/7	10/8	7/6	4/3	10/7	8/6	14/12	8/5	8/7	15/12	8/6	28/19	129/98	1.32
TOTAL	60/30	92/42	87/41	72/32	100/47	53/31	57/33	46/26	45/27	44/26	34/17	45/28	735/380	1.93
MGS	2.0	2.19	2.12	2.25	2.13	1.71	1.73	1.77	1.67	1.69	2.0	1.61		

birds being seen singly or in groups of two or three. This seems to be in remarkable contrast to the flocking behaviour of *Prosopeia* parrots in Fiji. Two explanations may be given:

1. The density of *Prosopeia* parrots is higher in Fiji than in Tonga. Hence accidental aggregations of larger numbers of parrots in fruiting trees are more likely.
2. Flocking is more likely in an avifauna with predators (cf. Pulliam & Millikan 1982): Fiji has three species of diurnal avian predators, whereas Tonga has none.

TABLE 2 — Frequency distribution of group sizes of feeding Red Shining Parrots. X: group size; n: number of observations.

X	1	2	3	4	5	6	t
n	147	139	70	21	2	1	380
n * x	147	278	210	84	10	6	735
%	20	37.8	28.6	11.4	1.4	0.8	

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CLUTCH OVERLAP BY A NEW ZEALAND PIGEON

By M. N. CLOUT, P. D. GAZE and J. R. HAY

ABSTRACT

The nesting behaviour of a New Zealand Pigeon (*Hemiphaga novaeseelandiae*) fitted with a radio transmitter was closely monitored in lowland forest at Pelorus Bridge Scenic Reserve. The bird and its mate nested in January 1985, and a single chick fledged in early March. At least one week before this chick left the nest the radio-telemetered parent started incubation on a second nest c. 100 m away. This second nest, and a subsequent one in late March, failed because of disturbance by predators. Clutch overlap as a breeding tactic by New Zealand Pigeons is discussed in relation to possible constraints on reproduction.

INTRODUCTION AND METHODS

New Zealand Pigeons are large (c. 650 g) colourful fruit pigeons which inhabit lowland forests throughout New Zealand. Their diet of fruits, leaves, buds and flowers has been well documented (McEwen 1978), but their behaviour and breeding biology are poorly known.

During a study at Pelorus Bridge Scenic Reserve, Marlborough (41°18'S, 173°35'E), we have gathered information on the breeding of New Zealand Pigeons equipped with radio transmitters. The transmitters on most birds either ceased working or fell off after a few months, and usually we could not retrap specific birds to attach new transmitters. However, one bird (known as Red C) was easily recaught and it carried two successive functioning transmitters for a continuous period of over 14 months. It was the only breeding bird to be monitored throughout an entire nesting season.

Red C, which was resident in our study area, was thought to be a male bird from its general behaviour. It was first mist-netted and marked on 11 October 1982, and it was recaptured on 4 October 1983 and 19 September 1984 at the same site. On the last capture it was fitted with a back-mounted radio transmitter (weighing c. 20 g). This functioned until 4 April 1985, when Red C was caught again and fitted with a new transmitter, which lasted until November 1985.

MOVEMENTS AND DIET

From September 1984 to November 1985 Red C was radio-tracked on at least 3 days per month. It had a well-defined home range of about 7.5 ha in tawa/podocarp forest and adjacent willows (*Salix fragilis*) and poplars (*Populus* sp.) by the Pelorus River (c. 30 m a.s.l.) but made occasional sallies of up to 600 m outside this usual range. Red C fed mainly on young leaves of willow and poplar from September to December; ripe fruits of wineberry (*Aristotelia serrata*), fuchsia (*Fuchsia excorticata*), tawa (*Beilschmiedia tawa*) and *Coprosma areolata* in January; ripe fruit of tawa and rimu (*Dacrydium cupressinum*) in February and March; ripe fruit of miro (*Prumnopitys ferruginea*) from March to July; and leaves of *Coprosma* species, *Schefflera digitata*, *Paratrophis microphylla*, and *Parsonsia heterophylla* from July to September.

NESTING CHRONOLOGY

Nest 1

Red C showed no breeding activity from 19 September to 13 December 1984. However, when next radio-tracked, on 15 January 1985, it was incubating on a nest in the canopy of a small tawa, c. 12 m above the ground. From 15 to 26 January, Red C incubated from at least 9.15 a.m. until about 6.30 p.m., when it was relieved by its mate (unmarked). We built an observation platform in an adjacent tree, from which we first saw the single chick on 29 January. It was fed twice and was brooded by Red C over the three hours it was under observation (11 a.m. to 2 p.m.). With a routine apparently similar to that during incubation, both parents brooded the chick until at least 1 February. From 7 February (when observations began again) until 6 March 1986, the chick was fed on the nest by both parents, but it was left unattended for most of the time. We observed it being fed only once a day by Red C, usually between 10 a.m. and 12.30 p.m. On 26 February the chick was caught on the nest at 9.30 a.m., weighed (400 g), fitted with a radio transmitter and replaced. It was fed by Red C at 12.30 p.m. and by the other parent at 4 p.m.

Nest 2

On 27 February, Red C was seen gathering nesting material and carrying it to a second nest c. 12 m up in a young totara (*Podocarpus totara*), c. 100 m from the first nest. When next radio-tracked, between 10 a.m. and 12.30 p.m. on 5 March, Red C was feeding on rimu fruit. It returned briefly to the first nest at 11.45 a.m. and may have fed the chick. At 2.15 p.m., when next located, Red C was incubating on the second nest. On 6 March, Red C was tracked continuously from 7.30 a.m. to 4.30 p.m. It was active throughout the morning, fed the chick in the first nest tree at midday, relieved its mate at the second nest at 12.30 p.m., and incubated there for the rest of the afternoon.

On our next visit, 11 March, we found that the chick had flown from the first nest and that the second nest had recently been preyed on. The egg was smashed on the ground, the nest was disturbed, and several contour feathers from a pigeon's back lay on the ground beneath the tree. Both parents apparently survived this attack because Red C was seen with presumably the same mate later that day. On 13 March, both Red C and the chick were radio-tracked and Red C was seen to feed the young bird at midday close to the site of the destroyed second nest. By 19 March the young bird from nest 1 had moved c. 200 m from its nest to an area just outside the normal range of Red C, where it fed on tawa fruit with at least three unmarked pigeons. On 26 and 29 March, the young bird fed on rimu and totara fruit on the margin of Red C's range, but it was also located 600 m south and 350 m north of the nest from which it had fledged. It was not seen with Red C after 13 March and had shed its transmitter by 1 April.

Nest 3

On 19 March, Red C and its mate were seen building a third nest 5 m up in a small tawa only 30 m from the first nest site. Red C performed display dives above this third site between 10 and 11 a.m. on 20 March, while its mate was sitting on the nest. By 27 March, incubation was being shared by both birds, the unmarked mate sitting in the morning and early afternoon and Red C taking over incubation at 2.15 p.m. This third attempt for the season by Red C ended when the egg was preyed on. Fragments of eggshell were found beneath the nest tree on 29 March with rat tooth marks on them. After this nesting failure no further breeding activity was detected in 1985. Red C fed alone on miro fruit until the fruiting season ended in July and then on foliage (sometimes with another bird) until its transmitter failed in November 1985.

DISCUSSION

Our observations are the first to demonstrate clutch overlap for New Zealand Pigeon and to suggest that some pairs could raise more than one chick per year.

Clutch overlap has been recorded in several bird families (Burley 1980), including the Columbidae (Robertson 1984), but its significance has received little attention. Burley (1980) concluded that it is used as a tactic to raise reproductive success when clutch size itself cannot be increased. By overlapping clutches during less demanding phases of offspring development, parents can increase the number of offspring reared per unit time. For example, Burley concluded that in Rock Pigeons (*Columba livia*) the clutch size is set at two because pairs cannot rear more than two young through the first week of life, when the parents produce a high-energy crop milk to feed their chicks. After this energetically limiting phase, pairs are able to start another clutch, while continuing to feed the chicks from the first clutch on normal foods such as seeds.

New Zealand Pigeons also feed their young nestlings on crop milk (Moon 1975). They lay only one egg, incubate it for 28-30 days and take a further 36-45 days to fledge their chick (Guthrie-Smith 1927, Wilkinson & Wilkinson 1952, Moon 1975). Egg-laying has been recorded in all months (OSNZ Nest Record Scheme, *Notornis* Classified Summarised Notes; pers. obs.) but mostly from November to March, perhaps timed so that young birds fledge in the fruiting season. The one-egg clutch is typical for a fruit pigeon, but Goodwin (1983) commented that the developmental period is remarkably long. He speculated that this was a response to low predation pressure in prehistoric New Zealand and the "possibly rather poor quality foods available". It seems unlikely that New Zealand Pigeons, in response to low predation levels, have evolved slow chick development to reduce further their already low reproductive rate. It is much more likely that the second speculation is correct, that slow development is a direct result of their entirely herbivorous, low-protein diet. Clutch overlap is a means of increasing reproductive output under a combination of constraints, namely the need to feed young nestlings on crop milk, the slow growth of the older chick, and the need to fledge young in the fruiting season. Red C saved at least one week by starting a second clutch before the first chick had fledged.

Although we have only this one example of clutch overlap, Red C was the only breeding bird to be monitored throughout an entire breeding season. We do not know if this was an isolated occurrence or the usual pattern for successful breeders. More research is needed into how common clutch overlap is among New Zealand Pigeons, whether it increases their reproductive output, and whether it is influenced by variations in the food supply provided by fruiting trees.

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THE NEW ZEALAND PASSERINE LIST: WHAT IF SIBLEY & AHLQUIST ARE RIGHT?

By R. N. HOLDAWAY

INTRODUCTION

Application of the technique of DNA-DNA hybridization to avian systematics has provoked much discussion and controversy (e.g., Feduccia & Olson 1982; Cracraft 1987; Sibley *et al.* 1987). This discussion is topical for New Zealand workers because several papers published by the chief proponents of the technique in avian systematics, C. G. Sibley and J. E. Ahlquist, have dealt with New Zealand birds. Indeed, two of their calibration points for relating rate of nucleotide sequence evolution to time are based on presumed events in the histories of the ratites, including the kiwis (Apterygidae) (Sibley & Ahlquist 1981), and of the New Zealand wrens (Acanthisittidae) (Sibley *et al.* 1982; Sibley & Ahlquist 1983). Although the assumptions involved in using these groups to calibrate the technique are also examples of some of its weaknesses, results of DNA-DNA hybridization studies could have substantial implications for the systematics of New Zealand birds.

The DNA-DNA hybridization method as applied to avian systematics has been evaluated by Houde (1987), who pointed out several difficulties with the rationale and presentation of results, but concluded that the method had considerable promise for elucidating systematic relationships below the level of Order. This is the level at which conventional techniques have encountered most difficulties. The problems, including the assumption of constant rate of genome evolution between groups, and presentation of tables of linear comparisons rather than complete data matrices, should not be overstated to the extent that the potential value of the method, if used carefully, is not fully exploited.

The purpose of this paper is not to discuss the details of the method or its problems but to apply the results of Sibley & Ahlquist's work on passerines of the Australasian region to the New Zealand passerine list. The list presented here includes the introduced species to give an indication of the radical changes in passerine systematics proposed by the authors.

The 'conventional' higher classification of the passerines has many weaknesses, particularly in such 'hold-all' families as the Muscicapidae, and this has been recognised for many years (Mayr & Amadon 1951: 14; Wetmore 1960: 16). The classification of the Australo-Papuan passerines given by Sibley & Ahlquist (1985) represents a series of new hypotheses on the relationships of many species. At the very least, their results can provide the basis for more critical studies (using conventional comparative anatomy, behaviour, biochemisty, and cladistics) of the relationships of New Zealand passerines.

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Apart from the early (and some very recent) work on anatomy, much avian taxonomy in Australasia has been based on external morphological characters and on the assumption (for example, by Mayr 1944) that most of the species in the Australian and New Zealand avifaunas resulted from repeated waves of colonisation from the north by groups which evolved in the Northern Hemisphere. Sibley & Ahlquist interpret their DNA-DNA hybridisation results as suggesting that some 'northern' groups had Australasian origins and that there has been considerable convergent evolution into similar niches. For example, the 'Australasian flycatchers' seem to be an artificial assemblage, none of which are particularly closely related to the Old World flycatchers with which they are placed in the New Zealand checklist. Some of Sibley & Ahlquist's (1987a) results suggest changes which may be necessary regardless of whether the classification itself is accepted; they include the submergence of *Finschia* in *Mohoua* and of *Bowdleria* in *Megalurus*.

The callaeatids, for which no data are yet available, and *Turnagra* are listed at the end as *incertae sedis*. Other departures from the 1970 Checklist (Kinsky 1970) are explained in footnotes.

The following list is not a formal checklist — it is an application of Sibley & Ahlquist's results to the New Zealand passerine fauna. All lists and classifications are explicit hypotheses on relationships within and between groups and must, perforce, be modified as knowledge increases. Stability of nomenclature is important, but the quest of stability should not become an obsession which inhibits the healthy questioning of opinion and dogma or the legitimate testing of hypotheses. If the list stimulates discussion of, and serious work on, the relationships, origins, and evolution of New Zealand passerines, it will have served its purpose.

LIST OF THE NEW ZEALAND PASSERINES, BASED ON THE RESULTS OF SIBLEY & AHLQUIST'S WORK ON AUSTRALO-PAPUAN AND NEW ZEALAND BIRDS

Order Passeriformes

Suborder *Tyranni (Suboscines)

Infraorder Acanthisittides

Family Acanthisittidae

Acanthisitta chloris (Sparrman, 1787)

Xenicus longipes (Gmelin, 1789)

Xenicus gilviventris Pelzeln, 1867

Traversia lyalli Rothschild, 1894[1]

Suborder Polymyodi (*Passeri)

Parvorder *Corvida

Superfamily Meliphagoidea

Family Meliphagidae

Notiomystis cincta (Du Bus, 1839)

Anthornis melanura (Sparrman, 1786)

Anthochaera carunculata (White, 1790)

Prosthemadera novaeseelandiae (Gmelin, 1788)

Family *Pardalotidae

Subfamily Acanthizinae

Gerygone igata (Quoy & Gaimard, 1830)

Gerygone albofrontata Gray, 1844

Superfamily Corvoidea

Family Eopsaltriidae

Petroica macrocephala (Gmelin, 1789)

Petroica australis (Sparrman, 1788)

Petroica traversi (Buller, 1872)

Family Corvidae

Subfamily Pachycephalinae

Tribe Mohouini[2]

Mohoua ochrocephala (Gmelin, 1789)

Mohoua albicilla (Lesson, 1830)

Mohoua novaeseelandiae (Gmelin, 1789)

Subfamily *Dicrurinae

Tribe Rhipidurini

Rhipidura fuliginosa (Sparrman, 1787)

Tribe Monarchini

Myiagra cyanoleuca Vieillot, 1818

Subfamily Corvinae

Tribe Corvini

Corvus moriorum Forbes, 1892[3]

Corvus frugilegus Linnaeus, 1758

Tribe *Artamini

Artamus personatus (Gould, 1841)

Artamus superciliosus (Gould, 1837)

Gymnorhina tibicen (Latham, 1801)

Tribe Oreolini

Coracina novaehollandiae (Gmelin, 1789)

Lalage sueurii (Vieillot, 1818)

- Parvorder *Passerida
  - Superfamily *Muscicapoidea
    - Family *Muscicapidae
      - Subfamily Turdinae
        - *Turdus philomelos* Brehm, 1831
        - *Turdus merula* Linnaeus, 1758
    - Family Sturnidae
      - Tribe Sturnini
        - *Sturnus vulgaris* Linnaeus, 1758
        - *Acridotheres tristis* (Linnaeus, 1766)

- Superfamily Sylvioidea
  - Family Hirundinidae
    - *Hylochelidon nigricans* (Vieillot, 1817)
    - *Hirundo tahitica* Gmelin, 1789
    - *Cecropis ariel* (Gould, 1843)
  - Family Pycnonotidae
    - *Pycnonotus cafer* (Linnaeus, 1766)
  - Family Zosteropidae
    - *Zosterops lateralis* (Latham, 1801)
  - Family Sylviidae
    - Subfamily Megalurinae
      - *Megalurus punctatus* (Quoy & Gaimard, 1830)

- Superfamily *Passeroidea
  - Family Alaudidae
    - *Alauda arvensis* Linnaeus, 1758
  - Family *Passeridae
    - Subfamily Passerinae
      - *Passer domesticus* (Linnaeus, 1758)
    - Subfamily Motacillinae
      - *Anthus novaeseelandiae* (Gmelin, 1789)
    - Subfamily Prunellinae
      - *Prunella modularis* (Linnaeus, 1758)

Family Fringillidae

Subfamily Fringillinae

Tribe Fringillini

Fringilla coelebs Linnaeus, 1758

Tribe Carduelini

Carduelis chloris (Linnaeus, 1758)

Carduelis carduelis Linnaeus, 1758

Carduelis flammea (Linnaeus, 1758)

Subfamily Emberizinae

Emberiza citrinella Linnaeus, 1758

Emberiza cirlus Linnaeus, 1766

Incertae sedis

'Callaeatidae'

Philesturnus carunculatus (Gmelin, 1789)[4]

Heteralocha acutirostris (Gould, 1837)

Callaeas cinerea (Gmelin, 1788)

'Turnagridae'

Turnagra capensis (Sparrman, 1787)

Turnagra tanagra (Schlegel, 1865)[5]

*Sibley & Ahlquist (1987b) list several changes to category names used in Sibley & Ahlquist (1985). For convenience, the changes relevant to the above list are (1985 names in parenthesis): Tyranni (Oligomyodi); Passeri (Passeres); Corvida (Corvi); Pardalotidae (Acanthizidae); Dicrurinae (Monarchinae); Artamini (Cracticini); Passerida (Muscicapae); Muscicapoidea (Turdoidea); Muscicapidae (Turdidae); Passeroidea (Fringilloidea); Passeridae (Ploceidae).

[1] *Traversia* was in general use before 1950 — e.g. Oliver (1930), Marples (1946), Mathews (1946), but not Buller (e.g. 1896), who persisted with his own nomenclature. The 1953 Checklist (Fleming 1953) lumped *Traversia* with *Xenicus* without comment or justification of the change other than a general statement in the preamble that the "list reflects the contemporary tendency to use broad genera". This policy seems to have been applied somewhat arbitrarily because ". . . the committee decided by majority vote to retain certain endemic monotypic genera in spite of their affinity with extralimital genera." The 1970 Checklist retained *Xenicus*, again without comment. The last systematic treatment (Oliver 1955) retained *Traversia*; this usage is followed here. Mayr (1979) followed the New Zealand Checklist, without comment.

[2] Sibley & Ahlquist (1987a).

[3] As originally described by Forbes. Further study is necessary before *Palaeocorax* Forbes, 1893 can be accepted as a valid taxon.

[4] Amadon (1962) used *Creadion*. The synonymy given suggests that the New Zealand Checklist is in error in retaining *Philesturnus*.

[5] I follow Olson *et al.* (1983) in recognising two species of *Turnagra*; their evidence for this is convincing, but their reasons for placing the genus in the Ptilonorhynchidae are less so. Similarly, the differences between the palates of the two forms of *Callaeas* (Oliver 1945) also argue for their separation as species.

COMPARISON WITH THE 1970 CHECKLIST

The main differences between the classification proposed by Sibley & Ahlquist and that followed by the 1970 Checklist are summarised below.

The Acanthisittidae is placed in its own infraorder of suborder Tyranni. This family has usually been placed with the suboscines. The latest morphological study, that by Raikow (1987) of the hindlimb myology, suggests that the Acanthisittidae was a very early branch of the oscines. This is, itself, at variance with results of studies of other single morphological features, such as the syrinx.

The Alaudidae retains familial status but is grouped with what are regarded as more 'advanced' groups in the Checklist order, the silvereyes (Zosteropidae) and sparrows (Ploceidae, now Passeridae), among others. The passerids *sensu* Sibley & Ahlquist are an amalgam of the Motacillidae (pipits), Prunellidae (accentors), and Ploceidae (sparrows and weavers). The Hirundinidae remains intact, but it too moves to near the more 'advanced' groups, in parvorder Passerida. Three families, the Campephagidae, Cracticidae, and Corvidae, represented here principally by vagrants and introduced species, are reduced to tribes of the new, very broad, family Corvidae. The Pycnonotidae, Zosteropidae, and Sturnidae retain their family rank, in parvorder Passerida; the Meliphagidae becomes a family of parvorder Corvida.

The remaining Checklist families are treated rather harshly by Sibley & Ahlquist's analysis. For example, the Muscicapidae is rent asunder, the Sylviinae and Turdinae being elevated to family rank in the Passerida (as Sylviidae and a newly defined Muscicapidae, respectively) and the Malurinae and Muscicapinae vanishing entirely. Part of the present Malurinae (*Gerygone*) is put in the family Pardalotidae, parvorder Corvida, while the remainder (*Mohoua*, with which *Finschia* is synonymised) is placed in subfamily Pachycephalinae of the new Corvidae. Similarly, *Petroica* becomes part of the new family Eopsaltriidae (Australian robins) while *Rhipidura* is placed with the monarch flycatchers in subfamily Dicrurinae of the new Corvidae. The Emberizidae is reduced to a subfamily of the Fringillidae, and the Carduelidae drops to tribal rank. The callaeatids and *Turnagra* remain *incertae sedis*, but data from *Philesturnus* should allow at least the Callaeatidae to find a place in the system.

The major features of relevance to the New Zealand list are the dismemberment of the old Muscicapidae (and so recognising the southern radiations of flycatcher-like birds strongly convergent with, but unrelated to, the Northern Hemisphere flycatcher/thrush/warbler assemblage) and the broad conception of the family Corvidae (which suggests a wide radiation into many different niches by groups with a close phylogenetic history).

The Sibley & Ahlquist classification provides explicit hypotheses of relationships between the families of the Passeriformes. This feature is lacking in present classifications, in all but the broadest sense provided by proximity in a linear arrangement. Some of the new placements, such as *Rhipidura* in the Corvidae and *Anthus* with the sparrows (Passeridae), are certain to raise eyebrows, and some scorn, but such hypotheses should be tested and not just rejected out of hand. Our present understanding of relationships is too meagre for us to be dogmatic. The suggestion of two major lines of oscine evolution is a radical departure from the status quo and is certain to arouse controversy; it should also provide a basis for further research.

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NOTE ADDED IN PROOF

In their Introduction to Vol. XI of the *Check-list of Birds of the World*, Mayr and Cottrell point out that "it had long been suspected that the Australian warblers and flycatchers had no relationship to the Sylviidae and Muscicapidae ... [but] ... in the absence of positive distinguishing characters and uncertainty as to their allocation, they were generally left with the Afro-Eurasian families. In recent years, however, the artificiality of this arrangement was so apparent that it became customary to recognize two indigenous families for the Australian warblers, Maluridae and Acanthizidae, one family for the monarch flycatchers (Monarchidae), a sub-taxon for the fantail flycatchers (Rhipidurinae), and a family for the Australasian robins (Eopsaltriidae)." In the apparent absence of diagnostic characters, but noting that "future modifications of this scheme are not precluded", Mayr and Cottrell have adopted "the scheme of branching pattern suggested by Sibley ... We regard it as a secure basis for future research."

The New Zealand species covered by this volume (Mayr, 1986) are the fernbird, the grey and Chatham Island warblers, the whitehead, yellowhead and brown creeper, the fantail, and the tomtits and robins. The fernbird is placed, as *Megalurus punctatus*, in the Sylviidae; the warblers as *Gerygone igata* and *G. albofrontata* in the subfamily Acanthizinae of the Acanthizidae. *Finschia* is retained and placed, with *Mohoua*, as subfamily Mohouinae of the Acanthizidae (*albicilla* is treated as a subspecies of *ochrocephala*); *Rhipidura* is placed in the subfamily Rhipidurinae of the Monarchidae; and the *Petroica*s are included in the Eopsaltriidae. [In a footnote, Mayr notes that Sibley (in MS, since published as Sibley *et al.*, see above) synonymises *Mohoua* and *Finschia* and considers them to be Pachycephalines.] Therefore, although the check-list editors express support for the DNA-DNA hybridization results, and the branching patterns in particular, their classification remains substantially the same as it would have been if recent custom had been followed. This was probably to avoid the considerable disruption that recognition of the revised families would have entailed, and the present treatment does, at least, express the independent evolutionary history of many Australasian passerines. After 55 years, the check-list series is complete; perhaps it is nearly time to start again.

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SEXING ADULT BLUE PENGUINS BY EXTERNAL MEASUREMENTS

By ROSEMARY GALES

In many species of penguins, the sexes differ in size (Croxall 1985), and in most, the males are about 10% heavier than females. This is apparent in Blue Penguins (*Eudyptula minor*) but the large annual variation in their body weight and the large overlap between sexes make weight unreliable for sexing.

The beak of *E. minor* is its most dimorphic character and the sexes of Blue Penguins of all the six subspecies can be distinguished by comparing the shapes of the beaks (O'Brien 1940, Kinsky 1960, Phillips 1960, Reilly & Balmford 1972, Kinsky & Falla 1976). These workers showed that in general the beak of the male is stouter and has a more acutely hooked tip on the upper mandible than that of the female. The female beak is more slender and tapered. However, this difference, although often described, has not been subjected to statistical analyses. In studying the Australian subspecies, the Fairy Penguin (*E. minor novaehollandiae*), in Tasmania, I have had to sex adults by their beak measurements and so could quantify the reliability of this sexing technique.

In Tasmania in 1984-1986, I sexed 136 adult Fairy Penguins either by dissecting freshly dead birds or by examining the cloaca for signs of swelling and distension at the time of egg laying (Serventy 1956). I measured the beak length (after Baldwin *et al.* 1931) and beak depth (after Warham 1975) of each bird to the nearest 0.1 mm. I analysed these data by Discriminant Function Analysis (DFA, Genstat) and calculated a discriminant score for each bird. DFA weights characters by their powers of discriminating between groups of unknown individuals, using data from individuals of known sex (reference, or known group).

With this technique I classified the sex of 107 Fairy Penguins (wild group), including 23 breeding pairs, which I measured in the field on Albatross Island (40° 24'S, 144° 32'E), Bass Strait, in the 1985/86 breeding season. By comparing the discriminant scores with the known group, I classified each bird as male or female. In addition, to examine the reliability of classifying sex by applying a single DFA, derived from the Australian subspecies, to penguins of a New Zealand subspecies, I calculated discriminant scores from the beak measurements of 40 Southern Blue Penguins (*E. minor minor*) of known sex. I had sexed these birds either by dissection or by cloacal examination (see above) in southern New Zealand between 1982 and 1984. The discriminant scores of these birds were then compared with the scores from the known-sex group of *E. minor novaehollandiae* and classified as male or female. The number which was

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incorrectly sexed by the DFA method was then used to provide an index of reliability of using a single DFA between subspecies.

RESULTS AND DISCUSSION

The mean beak measurements of the known groups of the two subspecies of *E. minor* are shown in Table 1. In both subspecies the differences between male and female beak measurements were significant but nonetheless showed considerable overlap. The difference between the beak lengths of the two known-sex groups was not significant for males ($t=1.50$, $df=88$, $p > 0.05$) or females ($t=0.82$, $df=84$, $p > 0.05$). However, the groups showed highly significant differences in beak depth (males: $t=4.89$, $df=88$, $p < 0.05$; females: $t=3.47$, $df=84$, $p < 0.05$), with *E. minor minor* having the larger beaks in both sexes.

TABLE 1 — Beak measurements (mm) of reference and wild specimens of *E. minor*

SPECIMENS	CHARACTER	SEX	N	MEAN	RANGE	SD	t-statistic
E.m. novaehollandiae reference group	length	M	66	39.1	36.0 - 42.3	1.44	9.94*
		F	70	36.8	34.0 - 40.1	1.17	
	depth	M	66	14.3	12.6 - 15.8	0.67	17.25*
		F	70	12.4	11.2 - 13.9	0.60	
E.m. novaehollandiae wild group#	length	M	51	38.7	36.4 - 42.0	1.07	9.51*
		F	56	36.5	34.2 - 40.1	1.32	
	depth	M	51	14.5	13.5 - 16.0	0.59	19.54*
		F	56	12.4	11.2 - 13.4	0.07	
E.m. minor reference group	length	M	20	38.8	36.8 - 41.8	1.48	2.54*
		F	20	37.4	34.2 - 40.9	1.95	
	depth	M	20	14.9	13.5 - 15.8	0.55	9.93*
		F	20	13.2	12.1 - 14.0	0.54	

* indicates $P < 0.05$
# sex classified by DFA

The classification formula which was derived from the *E.minor novaehollandiae* known-sex (reference) group was:

$$D = -83.10 + (10.06 \ln BL) + (17.99 \ln BD)$$

where D is the discriminant score, ln is the natural logarithm, BL is the beak length (mm) and BD is the beak depth (mm).

The sex of a Fairy Penguin can be determined by applying the bird's beak measurements to this formula. When D is positive, the penguin is classified as male, and when negative, female. Using this formula, of the 107 wild-group penguins measured in the field, I classified 56 (52%) as female and 51 (48%) as male (Table 1). As would be expected, there was no significant difference between the *E. minor novaehollandiae* known-sex group and the wild group (DFA classified sexes) in either beak length (males: $t=1.45$, $df=115$, $p>0.05$; females: $t=1.58$, $df=124$, $p>0.05$) or beak depth (males: $t=1.49$, $df=115$, $p>0.05$; females $t=0.004$, $df=124$, $p>0.05$).

The differences between the discriminant scores of males and females within groups were all significant (Table 2) and the distributions of these scores are shown in Figure 1. Of the 136 birds in the *E. minor novaehollandiae* known-sex group, 128 were classified as the correct sex, giving a classification reliability of 94%. The eight penguins which were incorrectly classified by the discriminant formula were four males with relatively small beaks and four females with relatively large beaks.

The numbers of males and females of the 107 wild-group penguins whose sex was classified by the discriminant formula represent a female:male sex ratio of 1:0.91, which compares well with that of 1:0.86 for the same subspecies found by Hodgson (1975). Of the 23 breeding pairs, every pair was classified as a male-female pair.

When I used the formula derived from the *E.minor novaehollandiae* known-sex group to classify the sex of the *E.minor minor* group, the formula classified only 31 of the 40 New Zealand birds as the correct sex. This represents a classification reliability between subspecies of 78%. All nine of the misclassified birds were females, which were classified as males. The relatively low level of reliability is a result of the larger *E.minor minor* beaks, as in Table 1. This is also evident in the differences in the discriminant scores between the two subspecies (males: $t=2.97$, $df=84$, $p<0.05$; females: $t=4.57$, $df=88$, $p<0.05$).

Table 2 — Discriminant scores of *E. minor*

SPECIMENS	SEX	N	MEAN	RANGE	SD	t-statistic
E.m. novaehollandiae reference group	M	66	1.59	-1.23 to 3.51	1.016	17.82*
	F	70	-1.49	-3.68 to 0.68	0.992	
E.m. novaehollandiae wild group	M	51	1.702	0.15 to 3.51	0.879	18.94*
	F	56	-1.57	-4.00 to -0.03	0.893	
E.m. minor reference group	M	20	2.317	1.13 to 3.88	0.738	8.83*
	F	20	-0.316	-2.57 to 1.23	1.111	

* indicates $P < 0.05$

The differences in the beak dimensions between the sexes and between the six subspecies of *E.minor* were illustrated by Kinsky & Falla (1976). From their data and my results, the conclusion is that a discriminant formula derived from one subspecies cannot be used reliably to sex other subspecies. Juvenile birds may make the difference worse. The beaks of *E. minor* fledglings are on average only 91% of the adult length and 81% of the adult depth (Gales, 1987) and the age at which they reach adult dimensions is not known. However, the formula presented here for adult Fairy Penguins in Australia gives a high reliability of classifying the correct sex from beak measurements. In practice, one can rapidly sex the adults of *E. minor novaehollandiae* in the field, at any time of the year, with 94% accuracy simply by taking the two beak measurements and calculating the discriminant score.

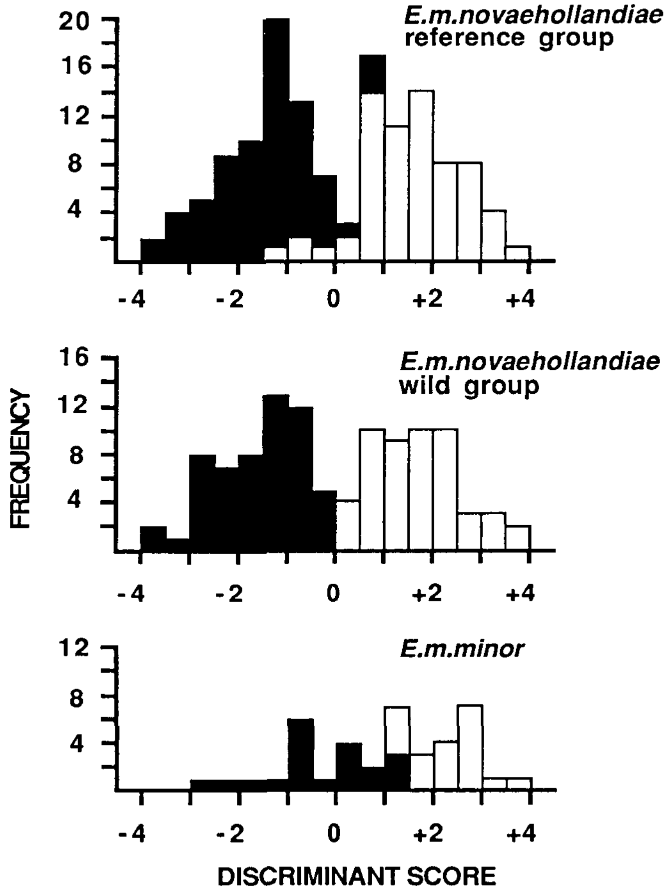

FIGURE 1 — Discriminant scores of female (solid) and male (open) reference specimens of *E.m. novaehollandiae* and of live specimens of *E.m. novaehollandiae* and reference *E.m. minor* classified as female or male

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SHORT NOTE

Southern Crested Grebes on a lowland coastal lake in winter

During the week of 18-24 July 1987, 52 lakes, ponds and lagoons throughout Canterbury were surveyed as part of the annual census of Southern Crested Grebes *(Podiceps cristatus australis)* and New Zealand Scaup *(Aythya novaezealandiae)*. One hundred and seventy-six Crested Grebes were found, the highest number recorded in Canterbury since our counts began in 1981 (unpubl. data) and only 17 short of the total count from a South Island-wide survey in 1980 (Sagar 1981). The most notable feature of the 1987 count was the discovery of 20 Crested Grebes on Lake Forsyth, a lowland coastal lake near Christchurch. An additional grebe was seen on nearby Lake Ellesmere at Kaituna Lagoon on the same day. Only Lake Alexandrina had more grebes (59 birds).

Lake Forsyth (680 ha) is a coastal lagoon adjacent to Lake Ellsesmere. It is long and narrow and surrounded by steep hills which are part of Banks Peninsula. The waters are highly eutrophic, often being discoloured with high concentrations of algae.

The Crested Grebes were scattered over the whole lake but two concentrations of 10 and 6 birds were seen feeding in loose flocks. All birds were in full breeding plumage. "Head shaking" (pair maintenance display), aggressive displays and chases were observed. A large number of Black Shags *(Phalacrocorax carbo)* and Little Shags *(P. brevirostris)* was also present on the lake, indicating that a rich source of fish, an important food for Crested Grebes, was probably present.

The grebes were counted each week for six weeks and their numbers declined steadily until none was left on 31 August (K. Harrison). The weekly counts were: 24 July, 20 birds (CO'D, P. McClelland); 30 July, 19 (P. Reese); 8 August, 15 (CO'D, P. Dilks); 14 August, 11 (K. Hughey); 19 August, 8 (PMcC, A. Grant); 26 August, 3 (PMcC).

This is the first time that a large group of Crested Grebes has been recorded on the east coast of the South Island. Single grebes and pairs have been found on Lake Ellesmere, Lake Forsyth, the Avon-Heathcote Estuary and Brooklands Lagoon, but only during severe winters in the high country when most lakes have frozen over. However, winter 1987 was very mild, and no lakes were frozen during the July survey. It appears that the Forsyth grebes may have come from the Alexandrina lakes, some 190 km from Banks Peninsula. Counts on all other lake systems produced about the same number of grebes as were recorded in previous years when lake conditions were similar. Only the Alexandrina count (59) was much lower than the 1986-1987 summer high of 100 birds (R. Nilsson, pers. comm.) The 20 grebes at Lake Forsyth would largely account for most of the 30+ grebes absent from Lake Alexandrina. The occurrence of birds on Lake Forsyth is the first case of "mass" movement to the coast, a behaviour which is common in the nominate race, *P. cristatus cristatus,* of Europe (Cramp & Simmons 1977) and occurs in *P. c. australis* within Australia (Frith 1969). Such movements were not recorded in New Zealand by Sagar & O'Donnell (1982), who suggested that, apart from stragglers, grebes did not undertake long-distance movements from their favoured alpine and subalpine lakes.

Thanks to Paul Sagar, Phil Moors and Richard Sadleir for commenting on this note.

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CALLS OF THE WHITE-RUMPED SWIFTLET

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Following the discovery that some swiftlets can echolocate in complete darkness (Medway 1959, Novick 1959), the species that can were separated from the genus *Collocalia* into the larger genus *Aerodramus* (Medway & Pye 1977). The White-rumped Swiftlet (*A. spodiopygius)* was placed in this genus because Pecotich (1974) had recorded that *A. s. terraereginae* in coastal Queensland and *A. s. chillagoensis* at Chillagoe (inland Queensland) produced the echolocatory *click* call. Subsequently this call and two other calls used at Chillagoe were described (Roberts *et al.* 1976).

This paper records four new calls for the species. Three of these are from *A. s assimilis* in Fiji and one from *chillagoensis.* It is confirmed that two of the previously described calls from *chillagoensis* are given by *assimilis.*

METHODS

During 4 days of continuous watching of chicks to study their feeding rates and during 10 hours of watching adult feeding behaviour, I wrote down phonetic versions of swiftlet calls in Fiji. In addition, I made two 1 hour visits to tape-record calls, which I later described in writing. Narrow band sonagrams of these recordings were made with a digital Sona-graph 7800 (Kay Elemetrics Corp.). Dry Cave (in which the tape recordings were made) and Waterfall Cave are at Nasinu 9 Mile, 14 km north of Suva. Ono Cave is in the Wainibuka Valley, 64 km north-west of Suva and Waiyala Cave is in the Sigatoka Valley, 40 km north of Sigatoka.

Observations on swiftlets at Chillagoe (Queensland, Australia) were made for 4 months during the 1985/86 and 1986/87 breeding seasons.

RESULTS

Echolocatory click call

The usual call of the White-rumped Swiftlet is a distinctive *click.* This call is given frequently in the twilight zone of caves used for roosting and breeding. It is used continuously for echonavigation by birds flying in total darkness. Birds clinging to the wall or being handled seldom gave it; and even when they did, they flapped their wings, as Harrisson (1966) found in the Mossy-nest Swiftlet (*A. vanikorensis*). The sonogram of the *click* call (Fig. 1) is characterised by a sharp wave front and rapid decay. Most energy is concentrated at 4-5 kHz, although the call ranges from 1 kHz to 8 kHz. On one sonagram, a harmonic was visible at 14-15 kHz.

The repetition rate of this call varied. On sonagrams of two birds, the time from the start of one *click* to the start of the next varied between

0.09 s and 0.173 s. Calls from live birds and recorded calls gave a mean rate of 4.0/s ± 0.23 ($\bar{x}$ ± SE, n = 22, range 1.4-5.9).

Birds flying swiftly along the narrow passage of Dry Cave, Nasinu, or those just frightened from their roost, appeared to call at a faster rate than those making repeated short flights from the wall in an effort to locate their nest. In Dry Cave individuals differed (by ear) in the pitch of their calls.

In the larger caves, such as Ono, Waiyala, and Waterfall Caves,the cacophony just after sunset of many hundreds of flying birds giving the *click* call was so great that I wondered how the call could have an echolocatory use. However, even when several thousand roosting birds were put to flight, the birds managed to move through the cave, though movement was slower.

The *click* call of a fledgling on its first flight is higher in pitch and noticeably quieter than that of the adult. However, this "thinner" call is enough to prevent juveniles from colliding with the cave wall, and the calls of adult birds help guide the juveniles towards the entrance instead of into other sections of the cave.

The chirrup call

To the ear this adult call was more highly pitched that the *click* call. The sonagram (Fig. 1) shows that the reason is not that the frequencies are higher than those of the *click* call, but that the higher frequencies within the same range are more sustained.

The most common form of the call is *chirrup, chirrup*. I have also heard *giddy up, giddy up* and *gar-p*. The call is used much less than the *click* call, mostly when a bird arrives at the nest. The bird already at the nest utters it to the new arrival as if in challenge or threat and yet as a means of identifying itself. If the incoming bird settles quietly, that is the end of the interaction. If the incoming bird replies, the result is a sharp vocal exchange or squabble, best described as a screech (shown on the right-hand side of the sonagram), which sometimes leads to a brief fight and the new arrival flying away. Such behaviour indicates that the arriving bird is probably not the mate of the brooding bird. The greeting call and threat display in the Common Swift (*Apus apus*) are similarly described (Lack 1956) as a high-pitched scream. Its function is not echolocation.

I heard the *chirrup* call used away from the cave only once when one bird joined another in its 25 m diameter feeding circuit. It is uttered by birds wheeling around above the entrance to a cave and usually whenever two birds are chasing each other.

At Chillagoe the call I heard given in such aerial pursuits is a long *tweet-tweet-tweet-tweet-tweet-tweet*, *peer-peer-tweet* or *tweer-tweer* that sounds like the scream that the Fijian *chirrup* call sometimes ends with.

The shree-ee call

At Chillagoe I heard a new call given only once. It was more shrill than any other call and was given when a flock had been dispersed from above a cave entrance by a Brown Goshawk (*Accipiter fasciatus*). Some minutes later the flock reassembled above the goshawk, occasionally giving this high-pitched *shree-ee* call, which had the indications of an alarm call. I do not have a recording of this call.

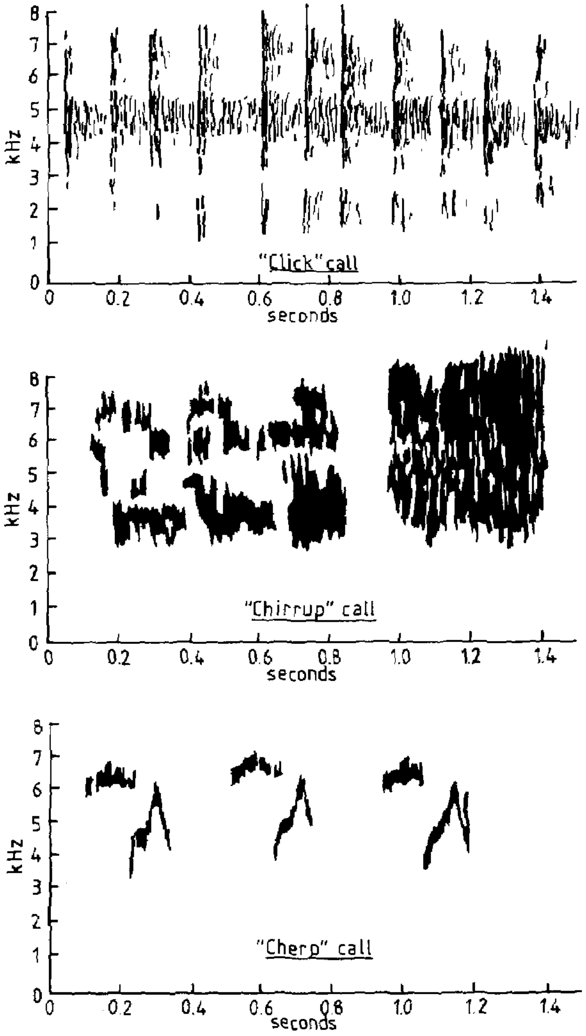

FIGURE 1 — Sonagrams of adult calls
The distinct broad bands of the *click* call are made less clear only by the echoes of the high energy signal at 4-5 kHz.
The portion of the *chirrup* call between 1.0 and 1.4s is the *simultaneous calling of two birds apparently as a threat call.*
The *cherp* call displays more refined melodic notes than the other calls.

The cherp call

This is the least common of the three adult calls given in Fiji. I have heard it only in the total darkness of a cave and then only rarely. It was given by roosting or recently landed birds. The call was a mellow yet fast *cherp, cherp, cherp*, much softer than the *chirrup* call.

The chick's begging call

This call usually starts as a plaintive whisper that develops into a demanding *cheep* and then a loud raspy call. As chicks aged, each stage of this call became louder and harsher. Sometimes the call started suddenly, close to the chick's full volume.

Begging, which accompanies this call, was often triggered by nearby chicks begging, an adult landing nearby, or an echolocating bird passing close by.

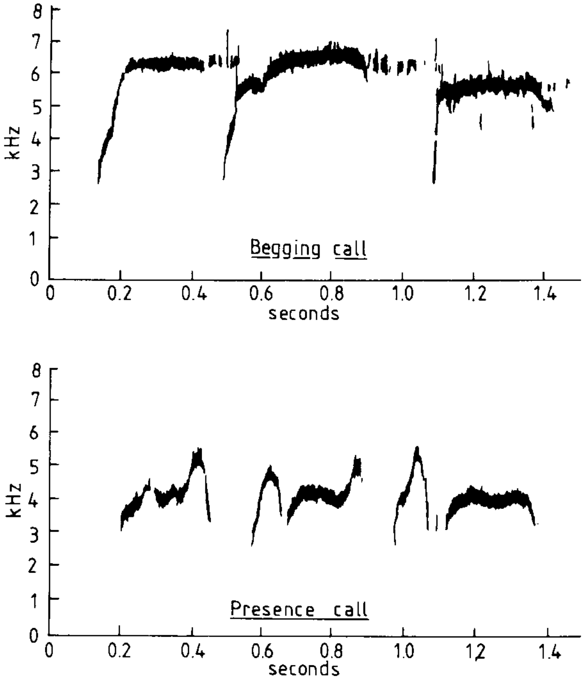

FIGURE 2— Sonagrams of chick calls
The begging call is more highly pitched and less melodic than the presence call.

The chick's presence call

This call is a single soft *cheep, chip* or *peep* that I noticed sometimes when the cave was quiet. What function it has, I do not know. The pattern on the sonagram shows its similarity to the *cherp* call of adults, and so it may be a subsong for that call.

DISCUSSION

Echolocatory click call

The echolocatory *click* call, called the *rattle call* by Medway (1959, 1962a,b, 1966, 1967) and Medway & Wells (1969), has been proposed as the basis for separating swiftlets with the call into the genus *Aerodramus* Oberholser (Medway & Pye 1977).

With these calls, White-rumped Swiftlets are able to detect rods down to 6.3 mm diameter (Griffin & Thompson 1982) but between 10 mm and 20 mm by Smyth & Roberts (1983). These authors agree that the *click call* is not sensitive enough to be used for nocturnal feeding because most swiftlet prey is too small to be detected with the low frequency of this call. The advantage of low-frequency calls is that they do not attenuate as quickly as high-frequency calls (Pye 1983). These findings do not mean that swiftlets cannot feed at all at night. The Indian Edible-nest Swiftlet *Aerodramus unicolor* (Kershaw *in* Ali & Ripley 1970) and the White-rumped Swiftlet (Tarburton 1987) have been observed feeding around lights at night. The Alpine Swift *Apus melba* (Freeman 1981) and the Chimney Swift *Chaetura pelagica* (Cottam 1932) also feed around lights at night, indicating that echolocation is not essential for night feeding. However, both authors indicated that the swifts were migrating, not nesting, when observed feeding nocturnally.

Being able to echolocate in the dark, White-rumped Swiftlets not only can nest in relatively safe sites but also can feed in rich feeding areas far from their nests during dawn and dusk, the times when aerial insects are the most abundant (Medway 1967, Hespenheide 1975, Tarburton 1986). While the latter function has been doubted (Fenton 1975) I have observed White-rumped Swiftlets feeding actively until last light 20 km from their roosting caves in Fiji. I have also recorded birds coming into Fijian caves as late as 2230 hours. That most of the birds had left the caves by 0430 hours that morning means that their echolocating ability allows them to make the most of the tropical day. Common Swifts cannot reach their nests or chicks if they arrive at the nest site a few minutes after dark (Lack 1956). Being able to echolocate, the White-rumped Swiftlets do not have this problem.

The echolocatory call is sometimes given by adults feeding in bright light and so may have another function as well as navigation. I have not heard lone feeding birds use it, but I have heard it soon after one feeding bird started to chase another. The call may therefore have a communication function. Even I could detect differences between the calls of birds in the quietness of Dry Cave, and so identification of individuals may be one function. Mercer (1966), Watling (1982) and Clunie (1984) apparently confused the chirrup call with the click call in describing a high-pitched twittering commonly used for echolocation in caves.

The *click* call is a double click similar to that of *A.s. terraereginae* in coastal Queensland (Roberts *et al.* 1976, Smyth & Roberts 1983). It has a pulse at each end of the *click* and so it sounds *cli-ik*, but the click is so fast that the two pulses are barely perceptible. The syringeal procedure for making this double click has been determined (Suthers & Hector 1982). In effect, the birds transform a longer squeak-like vocalisation into two brief clicks by momentarily closing the syrinx in the centre of the call. The call is not a clicking of the mandibles. Suthers & Hector suggested that, by generating these brief clicks, the swiftlets increase the bandwidth of their sonal signal. This bandwidth, having abrupt rise-decay times, should improve the birds' determination of target distance, which is based on measuring the pulse-echo interval.

Swiftlets using paired clicks, 20 ms or so apart, not only have better information on target distance but also have better knowledge of target velocity because, when the clicks are reflected, both the pitch and the time interval between the clicks are changed by the doppler shift (Pye 1983). This should enable the birds to avoid other birds or bats that might be flying in the same air space.

As a result of this call, the swiftlets of Fiji and Chillagoe have protected most of their nests and roost sites from predators by placing them in areas of total darkness.

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SHORT NOTES

A Study of Cattle Egret Numbers in the Horowhenua

Before our study began in 1983, Cattle Egrets *(Bubulcus ibis)* had visited the Horowhenua district only in very small numbers. E.B. Jones (1964) recorded the first birds – five in 1964 on fields at the southern end of Lake Horowhenua, a lake of about 400 ha lying immediately west of Levin. The fields at the southern end have remained the egrets' favourite site ever since. After 1964, E.B. Jones (1972, 1973, 1974, 1976) recorded one in 1966, up to five in 1973, and one in 1976. For the years leading up to 1980, Heather (1982) summarised records of 2-5 birds. An unexpected 12 birds on 1 December 1980 were presumably on passage and did not stay. Only a couple of birds visited our area in 1981 and 1982 (Powlesland 1982, Heather 1983).

Here we record our observations of Cattle Egrets at Lake Horowhenua from June 1983 to early 1987. Figure 1 shows the monthly maximum counts from at least weekly (and often daily) visits (over 200 in all) to the places regularly frequented by Cattle Egrets in late autumn, winter and spring, and less frequent visits in the summer and early autumn, when the egrets were generally absent. The trends shown support the trends shown nationally over these years.

On 11 June 1983, a flock of ten Cattle Egrets was seen flying over Arawhata Road at the southern end of Lake Horowhenua. These birds settled in trees on the eastern side of the road. By 16 June, this group had increased to 12, and they were feeding among dairy cows. We were able to approach within 50 m of them in a car (compared with 100 m on foot) and watch them taking flies off stems of grass and pulling worms out of the ground. By September some of the birds were showing colour and by 12 November seven were in full breeding plumage. On 17 November, only five birds remained, and by 22 November all had gone, presumably for Australia.

On 27 April 1984, four Cattle Egrets had arrived back in the Arawhata Road area. By 10 May there were 10 birds; 12 days later there were 42. On 19 June 64 were present, including a colour-dyed bird that had earlier been found exhausted at Te Horo, 10 km south of Lake Horowhenua. This bird had been banded as a chick at Lawrence, New South Wales, Australia, on

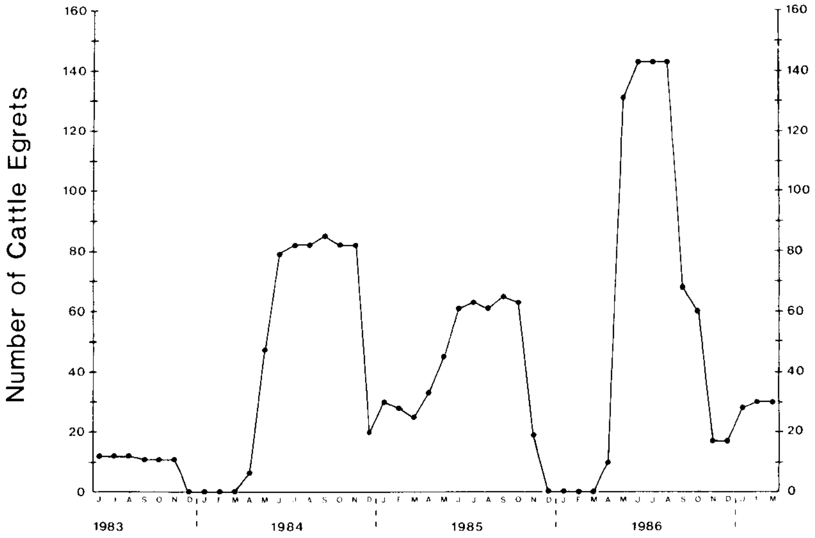

FIGURE 1 — Monthly maximum counts of Cattle Egrets at Lake Horowhenua

17 December 1983 and was taken to Nga Manu Trust Sanctuary to recover, before being released in late May, at Waikanae, with yellow dye on its breast. Numbers continued to increase until, by 20 July 1984, 82 were present. The peak number, recorded on 7 September, was 85. Breeding plumage was starting to show on about 60 birds at this time, and of the 60 birds remaining on 24 November, 45 were in full breeding plumage, the plumes on their backs being visible as they moved in the breeze, 10 were in various stages of colour, and 5 were white. Thirty of these birds spent the summer in New Zealand by moving 15 km north to the floodway of the Manawatu River just south of Foxton.

In 1985, the first Cattle Egrets back in the Horowhenua were two on 22 April. Three days later, five were present, and by 4 May 14 had arrived. The main influx occurred during the next few weeks because on 24 May there were 44 birds. Two of these birds were colour banded. From the colour combinations it was determined that one was 6 months old and had been banded as a nestling at Lawrence, New South Wales, but the other had lost a band and so could not be traced accurately. The highest count for the 1985 season was 65 on 15 and 22 September. The birds left Lake Horowhenua earlier than the previous year, only 19 being present on 18 November. The last sighting was of 10 on 23 November.

The first sighting in 1986, three birds on 4 April, was 18 days earlier than in 1985, and five more had turned up by 6 April. Numbers increased quickly to 49 on 4 May and 65 on 7 May. By this time, the two colour-banded birds seen in 1985 had returned. On 22 May, 131 birds were at the southern end of Lake Horowhenua, but these were in two flocks about

1 km apart: 68 at the Levin sewage ponds and 63 in the Arawhata Road area. These flocks were combined at the sewage ponds on 9 and 17 June, and a record 143 birds was recorded on both occasions.

Behaviour

When feeding near cows, Cattle Egrets happily wandered right underneath them, but we did not see them standing on the cows' backs as they do in Asia and Africa. Worms seemed to be their main food, apparently brought to the surface, or exposed, by the trampling action of the cows. Flies were also taken from seed stems of ryegrass, especially in warm weather. One bird was seen with a mouse in its bill, which it eventually swallowed. When not feeding with cows, the egrets have been watched moving across a paddock leap-frogging one another, the birds at the back of the flock flying over the front birds for food, much as flocks of Little Black Shags *(Phalacrocorax sulcirostris)* sometimes feed.

At sunset, the Cattle Egrets usually flew off to their roost trees in one flock, settling on the tops as high as they could get. On the other hand, at sunrise they would leave the roost trees in ones and twos, almost an hour passing before the last bird left the roost. They sometimes returned to the roost trees in the daytime, their pure white plumage from a distance making the trees look to be in flower!

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Predators together

On 11 April 1987, I was photographing harriers *(Circus approximans)* feeding on a dead rabbit that I had placed in front of my hide, on the Ohau river near Twizel. The day was fine, and I was in the hide from 9.30 a.m. to 1.30 p.m.

A dark brown juvenile harrier soon arrived but had just started to feed when it was attacked and driven off by an adult harrier. The juvenile circled the adult several times, attacked it, and drove it off. This behaviour was repeated many times, the two at first landing in a heap, clinging with their talons. Between attacks, the bird on the rabbit would shield it with outstretched wings. When a second adult arrived, they competed while the juvenile watched from the ground.

After about an hour, all three were driven away by a yearling wild tom cat (*Felis catus*), which was not fully grown. While the cat fed, the harriers circled above. About 20 minutes later, the cat ran into the scrub when I released the camera shutter. After 15 minutes, an adult male ferret (*Mustela furo*) appeared and began to feed on the rabbit. The cat reappeared, approached, bared its teeth and hissed, but the ferret took no notice. Both then fed, face to face. Eventually the cat departed, 10 minutes later the ferret departed, and the juvenile harrier returned to feed (the adults having long gone).

These predators should not have been unusually hungry. Rabbit numbers were high enough for the pest destruction board to poison the area 2 months later.

PETER COOK, *2 Fraser Crescent, Twizel*

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LETTER

Classical Origin of the Name *Daption* Stephens

Sibson's (1978, 1987) rather emotional and digressive essays on the gender of the generic name of the Cape Pigeon or Pintado do little service to the facts and ignore pertinent literature. There is no question that the letters in the word "pintado" can be recombined as "daption", but that *Daption* Stephens (1826) actually has its origins in a deliberately constructed anagram, as has frequently been assumed (Oliver 1968, Watson 1974, Sibson 1978, 1987), seems unlikely.

If it were simply an anagram, it would be a nonsense word that could not be inferred to conform to any rules of classical grammar and the pronunciation of which would be completely arbitrary, Sibson's (1987) remarks notwithstanding. In such instances in zoological nomenclature, the gender is determined by the original author's usage, which in the case of Stephens (1826), is consistently neuter, as correctly shown by Watson (1974).

Coues (1882: 126), under the name *Daptium capense*, attempted a classical derivation of *Daption*, as follows:

> Gr. [*daption*] or [*dyption*], a diminutive of [*dyptes*] or [*dytes*], a diver. This set of words vary in the vowels in different dictionaries, and may not all be found; compounds of them are seen in ornithology in *eudyptes*, *eudytes*, &c. They are all from one root. The above is almost universally written *daption*, but in transliteration from Greek to Latin becomes properly *daptium*.

Coues, ever the purist, was probably stretching a point in attempting to derive *Daption* from *dyptes*, even if such a vowel transformation is actually to be allowed. Nevertheless, it is significant that he regarded the name to be neuter in gender.

Choate (1973) comes much closer to the mark, though is still wide of it, in his derivation of *Daption*:

> Gr. *dapte*, 'devour'; L. *-ion*, suffix meaning 'having to do with.' The name may be explained by this quote from Murphy's *Oceanic Birds of South America*, 'Cape Pigeons are eager devourers of garbage and it would not be unnatural if bands of the birds sometimes pursued vessels a considerable distance.'

The stem should in fact be the Greek noun *daptes*, "an eater, consumer" (Liddell & Scott 1846:309). It can hardly be assumed that Stephens set out to create a *vox hybrida* by tacking a Latin suffix to a Greek root, and so the ending is surely the Greek diminutive suffix *-ion*, which is neuter. Thus *Daption* is a perfectly fine classical word meaning a "little devourer."

There are two pieces of internal evidence, one circumstantial, the other more substantive, indicating that this meaning is what Stephens (1826) intended. Firstly, Stephens, as already mentioned, clearly regarded *Daption* as neuter; yet if the word were only an anagram, there would be no reason to choose this gender over the more frequently used masculine or feminine. Secondly, the following passage from Stephens (1826:242) concerning the "Cape Pintado" provides ample reason for his choice of the Greek root "daptes": "They feed on fish and the dead carcases of whales, and are very voracious." Much more appropriate quotes from Murphy (1936:608) than that given by Choate above amplify Stephens' observation:

> . . . they are notoriously voracious birds . . . The food of the Cape Pigeon is as varied as its voracity is incredible. It may be called a glutton, in the human meaning of the word, not only because of its appetite but equally because each Cape Pigeon seems to dislike to see another eating as much as it enjoys the process itself!

In all likelihood, Stephens had precisely this attribute of the Cape Pigeon in mind when he coined the name *Daption*, which name would therefore be of purely classical origin and would not have been purposely, or at least not primarily, intended as an anagram. In either case, however, its gender is unequivocally neuter, so that the specific name of the Cape Pigeon must be rendered *Daption capense*. Sibson's (1978, 1987) assertions that this treatment is "insulting" and the deprives the bird itself of sex are silly and have no place in serious discourse. "*Gender* is a grammatical term . . . To use *gender* as if it were synonymous with *sex* is an error, and a particularly unpardonable one in scientific writing" (Bernstein 1973:199).

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