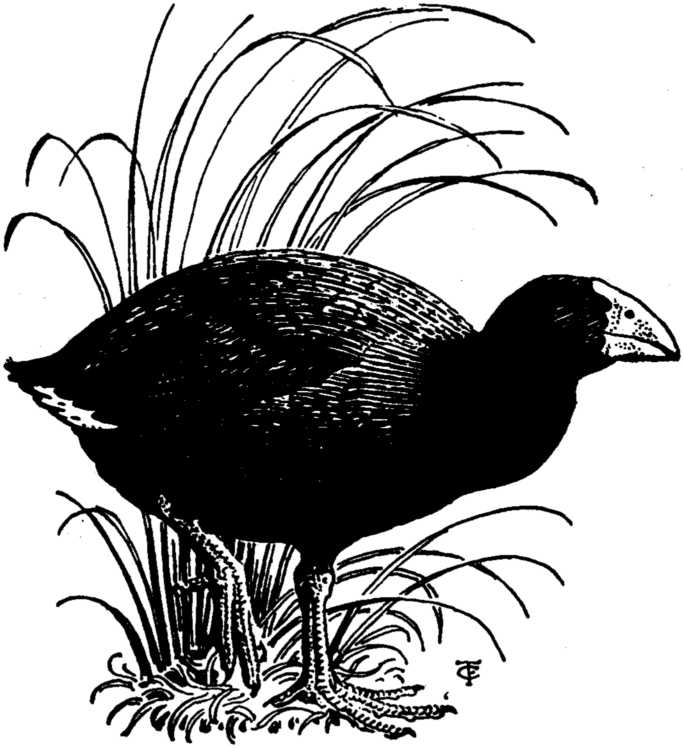
NOTORNIS

Journal of the Ornithological Society
of New Zealand



Volume 36 Part 1 March 1989

20th INTERNATIONAL ORNITHOLOGICAL CONGRESS 1990

Final Notice

The 20th International Ornithological Congress will take place in Christchurch, New Zealand, on 2-9 December 1990. The Congress programme will include 7 plenary lectures, 48 symposia, contributed papers (spoken and poster), workshops, round-table discussions and films. There will be a mid-Congress excursion day. Longer tours are planned to interesting ornithological sites in New Zealand before and after the Congress, including the post-Congress cruises to subantarctic islands.

The Second and Final Circular of the Congress will be available from 1 October 1989 and will include the registration papers and forms for submitting papers. In late 1990 New Zealand will also host the 20th World Conference of the International Council for Bird Preservation in Hamilton on 21-27 November 1990 and a Pacific Festival of Nature Films in Dunedin on 27 November - 1 December 1990. Requests for the Final Circular, which includes information on the above events, should be sent to:

Dr Ben D. Bell, Secretary-General,
20th International Ornithological Congress,
School of Biological Sciences,
Victoria University of Wellington,
P.O. Box 600, Wellington, New Zealand
(Telex NZ30882 VUWLIB; Facsimile NZ 64-4-712070)

ISSN 0029-4470

CONTENTS

Short Notes

Printed by TE RAU PRESS LTD, Peel Street, Gisborne

REGIONAL REPRESENTATIVES

FAR NORTH: Vacant.
NORTHLAND: David Crockett, 21 McMillan Ave., Kamo, Whangarei.
Ph. 50-954.
AUCKLAND: Michael Taylor, 28 Awarua Crescent, Orakei, Auckland 5.
Ph. 549-234.
SOUTH AUCKLAND: Anthea Goodwin, RD2, Papakura,
Ph. 292-886, Auckland
WAIKATO: Stella Rowe, 1 Corrin St., Hamilton. Ph. 435-199
BAY OF PLENTY: Paddy Latham, 72 Simpson Road, Papamoa Beach,
Ph. 420-406 Tauranga.
VOLCANIC PLATEAU: Martin Day, 7 Branch Street, Lake Okareka, Rotorua.
Ph. 28-122
GISBORNE/WAIROA: Jim Henley, 6/456 Aberdeen Rd., Gisborne.
Ph. 81-581.
TARANAKI: David Medway, 25A Norman Street, New Plymouth. Ph. 80-370
MANAWATU: Lindsay Davies, Stace's Road, RD1, Palmerston North.
WANGANUI: Ph. 70-159.
HAWKES BAY: Wayne Twydle, 124 Nelson Cres., Napier. Ph. 356-563.
WAIRARAPA: Tenick Dennison, 129 Renall Street, Masterton.
Ph. 85-200
WELLINGTON: Kerry Oates, 12 Jackson Terrace, Ranui Heights, Porirua.
Ph. 379-126
NELSON: Jenny Hawkins, 772 Atawhai Drive, Nelson. Ph. 520-151.
MARLBOROUGH: Beverley North, P.O. Box 341, Blenheim. Ph. 88-585.
CANTERBURY: Barry Armstrong (acting), 60 Frankleigh Street,
Christchurch 2. Ph. 324-784.
WEST COAST: Stewart Lauder, 9 Winnie Street, Greymouth. Ph. 6349.
OTAGO: Peter Schweigman, 121 Maryhill Terrace, Maryhill, Dunedin.
Ph. 52-790.
SOUTHLAND: Maida Barlow, 38 Filleul Street, Invercargill.
Ph. 83-580

LITERATURE AVAILABLE

From all bookshops:

New Guide to the Birds of New Zealand, by R. A. Falla, R. B. Sibson and E. G. Turbott	$30.25

From Tom and Hazel Harty, R.D.2, Drury, South Auckland:

Back numbers of NZ Bird Notes & Notornis

Reports & Bulletins (1939-1942), 1953 reprint	$ 5.00
Volumes 1-25 (1943-1978)	$ 5.00 per part
Volume 26 onwards	$10.00 per part
Index (vol. 5 onwards)	$ 5.00 per vol.
OSNZ Library Catalogue (1976 ed.), 17 pp.	$ 1.00
1980 Amendments & Additions to 1970 Checklist	$ 2.00

Packaging & postage extra. For NZ orders add 10% GST.

Overseas requests to recommend NZ bird books will be answered, and overseas orders for them will be passed to a reputable bookseller.

NOTORNIS

is the journal of the Ornithological Society of New Zealand (Inc.)

Editor B. D. Heather
10 Jocelyn Crescent
SILVERSTREAM

VOLUME 36 PART 1 MARCH 1989

RESPONSES OF HARRIERS IN THE MACKENZIE BASIN TO THE ABUNDANCE OF RABBITS

By R. J. PIERCE and R. F. MALONEY

ABSTRACT

Harrier diet and population dynamics were studied at Tekapo River in 1985 and 1986, and stomach contents were analysed from 239 specimens collected in the Cass Valley in 1983-85. Harriers in both study areas fed mainly on rabbits, including young live rabbits and carrion. Local changes in rabbit abundance led to changes in the distribution and numbers of harriers. Immature harriers were mainly transients and responded to changes in rabbit numbers more than adults did. When rabbits were scarce, the resident harriers fed more on alternative prey, such as skinks, but there was no corresponding increase in the numbers of birds eaten. Males fed on alternative prey more than females did. Males were outnumbered by females in the study area with lower prey diversity.

INTRODUCTION

In New Zealand, Australasian Harriers *(Circus approximans)* are flexible in the habitats they frequent and the food they eat (Baker-Gabb 1986). They are particularly common in the MacKenzie Basin and in other tussocklands east of the Southern Alps, where there are high numbers of rabbits *(Oryctolagus cuniculus)*. In Otago in 1949, before large-scale rabbit control was under way, Gurr (1968) found rabbit remains in the stomachs of 90% of 331 harriers. Since then there have been few studies of high country harriers: Douglas (1970) found mainly remains of hare *(Lepus europaeus)* in regurgitated pellets cast at one nest, and Pierce (1986) found infrequent evidence of harrier predation at nests of stilts (*Himantopus* spp.).

The present study was supplementary to research on feral cats *(Felis catus)* and ferrets *(Mustela furo)*, designed to help understand patterns of predation intensity on riverbed birds. The main goal was to establish the responses of predators to fluctuating densities of rabbits, their staple food. For harriers, we examined whether depleted rabbit numbers would cause the birds to hunt elsewhere (numerical response) or to vary their diets and remain within the original area (functional response).

NOTORNIS 36: 1-12 (1989)

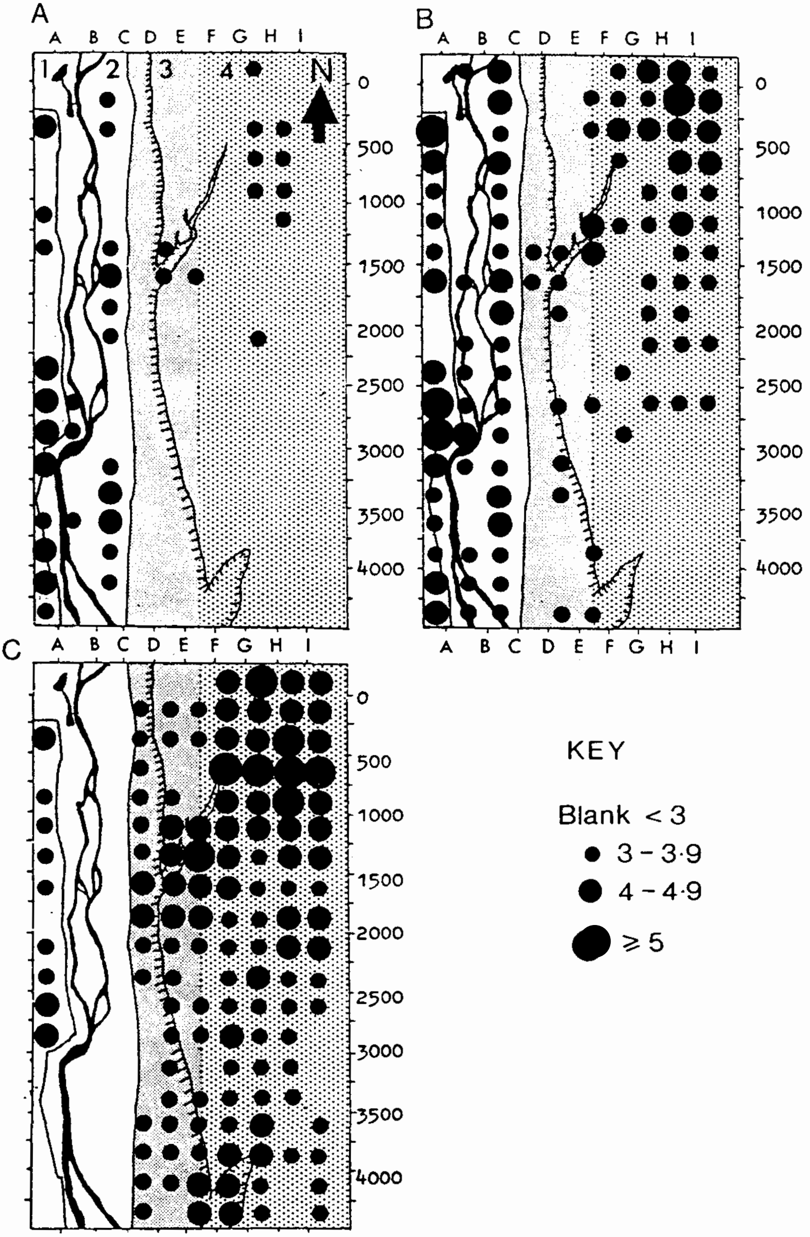


FIGURE 1 — Zones 1-4 of the Tekapo study area and indices of rabbit abundance in three years. Size of dot denotes scale of rabbit sign (see key) and follows Anon (1968). A. March - May 1985; B. March - April 1986; C. February 1987

Like most raptors, harriers are sexually dimorphic in reverse, females being larger than males (Carroll 1970). Overseas studies have revealed dietary differences between the sexes in several raptor species (Newton 1979). In the Manawatu, Baker-Gabb (1981 and unpub.) found that harriers preyed on a variety of animals and that females fed on larger prey than males. We were interested in finding out whether there were sex- or age-related differences in diet in the MacKenzie Basin, or whether rabbits were of equal importance to all cohorts.

STUDY AREAS

The main study area, 8.5 km², comprised mainly tussock grassland, flanking the bed of the Tekapo River (44°05' S, 170°25' E) at 590-700 m a.s.l. We divided the study area into 250 m grid-squares bordered by lines A-I and rows 0-4250 (Fig. 1). Within this area we recognised four zones. Zone 1 on the western side of the river (grid-line A of Fig. 1) comprised a well-vegetated terrace edge, bordering extensive tussock *(Festuca)* grassland. Zone 2 comprised the bed of the Tekapo River (grid-lines B and C), which had diverse vegetation ranging from herbfields and rank grass to thick matagouri *(Discaria toumatou)* and patches of willows (*Salix* spp.). Zones 3 and 4 (grid-lines D-I) comprised a plateau of tussock grassland and a 25-30 m high terrace slope between grid-lines D and E. Rabbit-netting fences ran parallel to grid-lines A and C, thus separating the rabbits into three groups – zone 1, zone 2 and zones 3-4.

North of the study area was a cluster of artificial ponds (Patterson's Ponds) surrounded by tall grass. The study area has warm summers and cold winters. The 1986 winter was colder than usual with about eight weeks of snow cover, compared with about two weeks of snow cover in 1985.

Supplementary data were collected along the south-west bank of Cass River (43°50' S, 170°25' E), 25 km north of Tekapo River. The Cass River is in a deep valley, 710 m a.s.l. at the base, rising to 2000 m on the flanking Joseph Ridge. Like the Tekapo study area, the Cass Valley was mainly tussockland: it was more fully described by Pierce (1983).

METHODS

In the Tekapo study area, we captured harriers in wire cages (mammal traps) located at the grid points. The cages, 610 mm long, 340 mm wide and 300 mm high, were baited with rabbit meat from which all hair, claws and teeth had been removed. We aged harriers from the presence (adult) or absence (immature) of underwing barring (Baker-Gabb 1981), sexed them from the size of the feet and talons, which are larger in females (Carroll 1970), and banded them. About every 10 days, we checked for vehicle-killed harriers along 33 km of main road (all 3-9 km away) to the east, north and west of the study area. We searched for harrier nests along about 10 km of the Tekapo River bed (including the study area) and on the adjacent plateau.

Harriers regurgitate pellets of undigested parts of prey such as bones, hair and feathers. Birds often disgorged pellets while perched on fence posts in the study area. At the end of each month, we collected these pellets and soaked them in water before analysing them. We could not always distinguish remains of rabbit from remains of hare. However, all of the lagomorph hard parts that we could identify were of rabbit, and so in the results and discussion sections we refer to "lagomorphs" as "rabbits". We could often estimate the approximate size of rabbits eaten by measuring claw lengths and comparing them with claw lengths of rabbits of known weight.

The main limitation of analysing pellets of harriers is that some prey, such as nestling birds, leave few or no remains (Schipper 1973), giving rise to biased results. Nevertheless, pellets can show general patterns of feeding behaviour between seasons and between habitats. Except for some captured harriers which regurgitated while they were in the cages, we did not know the age and sex of the birds which deposited the Tekapo River pellets. These pellets may have been biased towards the adult harriers that defended territories over both of the fence lines. One sample of 80 pellets collected at a harrier roost at Patterson's Ponds (where up to 30 birds were seen at once) may have been biased towards immatures.

In the Cass Valley, many harriers were trapped and killed by staff of the Department of Conservation in and around nesting areas of Black Silts *(Himantopus novaezelandiae)* during September-December in 1983, 1984 and 1985. The sex of these birds was first estimated externally. Subsequent autopsy and gonadal inspection showed that external sexing gave 95% accuracy. For all analyses of pellets and stomach contents, data are presented as percent occurrence. Volumetric or biomass assessments were unnecessary, owing to the very high proportion of one prey type: rabbits.

THE PREY

Rabbits were very common in both study areas, but there were seasonal and annual variations within each area. In the Cass Valley, rabbits were at a high density during spring 1983, but extensive poisoning (carrots impregnated with compound 1080) by the Tekapo Pest Board in autumn 1984 resulted in low rabbit densities in 1984 and 1985. MacLean Scale indices of rabbit abundance (on a 1-10 scale and based on frequency of rabbit droppings, Anon 1968) were 4-6 during the 1983 season (D. May, pers comm.), but averaged only about 2 in 1984 and 2-3 in 1985 (pers. obs.).

In the Tekapo study area, two poisoning operations dominated rabbit numbers. Zones 3 and 4 had been poisoned in August 1984, and rabbit indices increased markedly throughout the study (Fig. 1, A-C). In zone 2, rabbits were moderate to common until they were poisoned in May 1986 and few rabbits survived there in winter and spring 1986 (Fig. 1C). In zone 1 and the tussockland to the west, rabbits were common throughout the study.

Rabbits were born in all months in the Tekapo study area, but mostly from August to November. Young rabbits were commonly seen from October to March. The 1984 breeding season was a very poor one for rabbits in zones 3 and 4, apparently because ground predators were feeding heavily on nestling and juvenile rabbits (unpub. data). Thus, during autumn and winter 1985 juvenile rabbits were relatively scarce in zones 3-4, compared with the following 18 months, when they were common.

In both study areas, the avifauna was dominated by charadriiforms (e.g. Pierce 1983) and especially introduced passerines, both groups being more common in the Cass Valley. Of the lizards, common skinks *(Leiolopisma nigriplantare macanni)* were widespread and common in both areas, while zones 1-3 of the Tekapo study area also had localised populations of long-toed skinks (undescribed species), *L. chloronoton* and/or *l. lineoocellatum* and

Heteropholis gemmeus. The nocturnal common gecko *(Hoplodactylus maculatus)* also was in zones 1-3 and in the Cass Valley. Large diurnal terrestrial insects were few, mainly grasshoppers (e.g. *Sigaus australis*), which were very common in the Cass Valley but rare in the Tekapo study area. Small numbers of hares *(Lepus europaeus)* were in both study areas, but they became very rare on zones 3 and 4 of the Tekapo study area during the study, none being seen there from autumn 1985 to winter 1986.

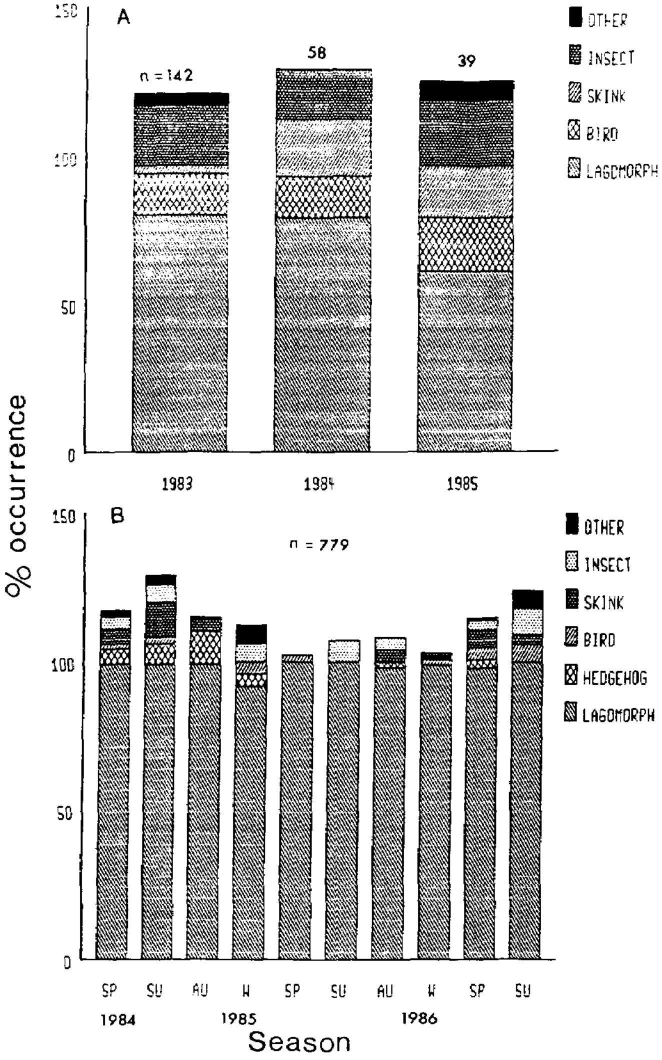


FIGURE 2 — Diet of harriers. A. Contents of harrier stomachs, Cass Valley, September - December 1983-85. B. Contents of pellets collected monthly at Tekapo River

RESULTS

Changes in diet

In the Tekapo study area rabbit remains occurred in 98.5% of pellets. After rabbit poisoning there in 1984, many pellets also contained hedgehog and skink remains (Fig. 2B). Few young rabbits (< 500 g) were recorded in pellets in 1984, but they were recorded much more frequently in 1985 and especially in 1986 (Table 1).

TABLE 1 — Estimated weights of lagomorphs eaten or partly eatan by harriers at Tekapo River

Season	N	Lagomorph weight (g)			
		< 100	100-500	> 500	Unknown
Spring 1984	116	3	9	9	80
Summer 1984-85	104	3	24	5	68
Autumn 1985	74	0	8	7	85
Winter 1985	46	4	22	15	59
Spring 1985	55	8	36	2	55
Summer 1985-86	55	20	20	2	58
Autumn 1986	43	0	21	9	70
Winter 1986	80	5	16	18	61
Spring 1986	155	30	32	5	34

Note: 1. Data presented as % occurrence.
2. Lagomorphs of "unknown weight" are all over 100 g.
3. "Spring" = Sep-Nov, "Summer" = Dec-Feb, etc.

In the Cass Valley, harrier stomachs contained fewer rabbits (61-80%; $x^2 = 9.04$, $p < 0.01$) and contained more alternative food than Tekapo pellets (Fig. 2). As at Tekapo, skinks were eaten more after rabbit poisoning. Thus, skinks occurred in 3% of crops in 1983, 19% in 1984 and 18% in 1985 ($x^2 = 13.1$, 2 d.f., $p < 0.01$). In 1985, a reduction of rabbits as prey and an increase in birds were not significant ($x^2 = 1.4$, 2 d.f., $p > 0.1$).

TABLE 2 — Birds identified in harrier pellets (Tekapo River) and in stomachs (Cass River)

	Tekapo	Cass
Number examined	779	239
Duck egg (Anas sp.)		2
Duckling		1
Banded Dotterel chick		2
Black-backed Gull	1	
Black-fronted Tern egg	1	
Black-fronted Tern chick		1
Blackbird	1	
Skylark	4	7
Goldfinch		1
Greenfinch	1	
Redpoll		1
Chaffinch	1	
Yellowhammer	1	4
Unidentified passerine	3	4
Unidentified bird	3	12
Total birds (and % occurrence)	16 (2.1)	35 (14.6)

Birds (mainly passerines, Table 2) and their eggs occurred in 15% of Cass crops and 2% of Tekapo pellets and there were no significant inter-year differences. Fish were not recorded in pellets from either study area, but a sample of 87 pellets collected from a harrier roost at Patterson's Ponds, on 2 August 1985, included three with fish remains. There were two observations of harriers catching trout (*Salmo* sp.), one of 400 g from Patterson's Ponds and one from the hydro canal.

TABLE 3 — Numbers and percent occurrence of food items in harrier stomachs Cass River September-December 1983-86

	Adult males	Adult females	Immature males	Immature females	Total
No. examined	37	36	81	85	239
Lagomorph	26 (70)	30 (83)	57 (70)	71 (84)	184 (77)
Hedgehog	1 (3)	1 (3)	2 (2)	0	4 (2)
Sheep	1 (3)	0	0	3 (4)	4 (2)
Mouse	1 (3)	0	0	0	1 (<1)
Bird	5 (14)	5 (14)	16 (20)	9 (11)	35 (15)
Skink	3 (8)	3 (8)	10 (12)	6 (7)	22 (9)
Insect	6 (16)	3 (8)	27 (33)	12 (14)	48 (20)
Total items	42	41	110	99	292

Note: Figures in parentheses are % occurrence.

Sex- and age-related differences in diet

In the Cass Valley, the diet varied between the sexes (Table 3). Small prey (birds, skinks, insects or mice) occurred in 58% of male crops compared with only 31% of female crops ($x^2 = 9.30$, 1 d.f., $p < 0.01$). Small prey were most frequent in immature males (65% of crops), followed by adult males (41%), immature females (32%) and adults females (31%). This difference was significant between immature males and immature females ($x^2 = 9.81$, $p < 0.01$) and between immature males and adult females (x^2 5.55, $p < 0.05$) for the three years combined. (These differences were also significant for the 1983 season alone, the only year in which sample sizes were large enough to permit single-season analysis.)

Rabbit remains tended to occur more frequently in female crops (83-84%) than male crops (70%), but this difference was not significant ($x^2 = 1.32$, 1 d.f., $p > 0.05$).

TABLE 4 — Monthly occurrence of dead harriers on roadsides in the Tekapo area

	1985						1986									
Age/sex	J	J	A	S	O	N	F	M	A	M	J	J	A	S	O	Total
Adult male												3				3
Adult female								1		1		3	1			6
Immature male			1									3	1			5
Immature female			1					4				2	2		1	10
Unknown	4	3	3	1			1	5	2			2		1		22
Total	4	3	5	1			1	10	2	1	0	13	4	1	1	46

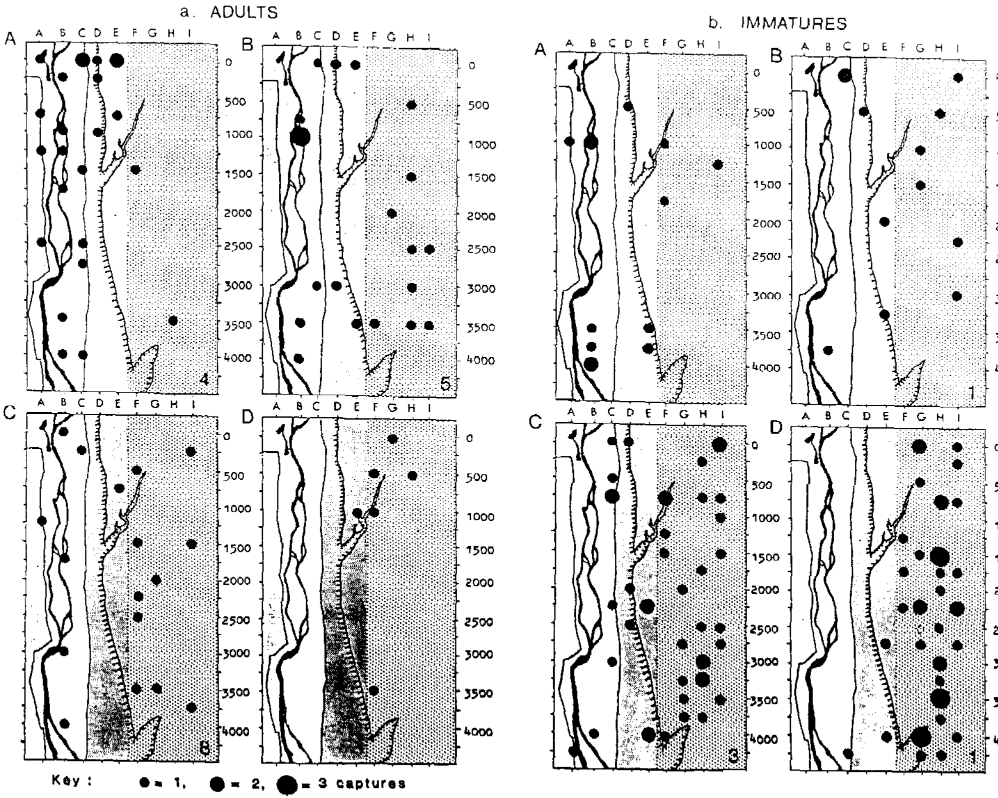


FIGURE 3 — Distribution and number of captures of (a) adult and (b) immature harriers Tekapo River. Time periods are A. February - August 1985; B. September 1985 - January 1986; C. February - August 1986; D. September - December 1986. The numbers in the lower right-hand corners denote number of recaptures.

Scavenging

Not all rabbit food was initially killed by harriers. An unknown proportion of food was scavenged from roadside carcasses over 4 km from the Tekapo study area. From June 1985 to October 1986, we found dead a total of 46 harriers (including four adults banded in the study area) along 33 km of road east, north and west of the study area. Half of these dead birds were found in two months only – March 1986 (mostly juvenile birds) and July 1986 (the only month with continuous snow-cover). Because the Cass Valley is 12-20 km from the main road, resident harriers there had little access to roadside carcasses.

Harriers also scavenged on remains of rabbits which cats had killed and left in the open or in areas of matagouri scrub, where they would have been visible to flying harriers. After rabbit poisoning in the riverbed in May 1986, harriers were conspicuous as they ate carrion for up to 6 weeks after the poisoning. We found no evidence of secondary poisoning of harriers.

Capture sites

There was a marked change in the distribution and numbers of harriers captured during the Tekapo study (Fig. 3). During the early part of 1985, adult and immature harriers were caught mostly on or near the riverbed, but by late 1986 nearly all captures were in zone 4. This difference was significant for adults between trapping sessions A and C ($D = 0.51$, $p < 0.01$) and for immatures between sessions A and C ($D = 0.49$, $p < 0.05$) and A and D ($D = 0.78$, $p < 0.001$ Kolmogorov-Smirnov $D+$ test).

Overall capture rates increased from about 1.2 per 100 trap days in 1985 to 3.1 per 100 trap days in 1986. This increase in capture rate was a result of more immatures in the area: immatures had comprised only 35% of the captured sample in Feb - Aug 1985 and 36% in Sep 1985 - Jan 1986, but this had increased to 71% in Feb - Aug 1986 and 85% in Sep - Dec 1986. Of the immatures captured, 62% were females ($x^2 = 5.76$, $p < 0.05$; Table 5), but in the Cass Valley 51% of immatures were females (Table 3).

TABLE 5 — Recoveries of Tekapo River harriers 1985-86

	Number banded	Number of recoveries	Number of individuals recovered	Distance between sites (km)		
				Max.	Min.	Average
Adult male	22	12	9	20	0.5	5.7
Adult female	20	10	7	4	0.5	1.1
Immature male	38	4	2	850	2.0	280
Immature female	62	7	7	560	1.7	126
Pullus male	4	0	0			
Pullus female	3	2	2	2	1.8	1.9
Total adults	43	24	17	20	0.5	2.8
Total immatures	105	11	9	850	1.7	159
Total pulli	9	2	2	2	1.8	1.9

Note: Totals include some unsexed birds.

Dispersal of banded birds

All 17 adults recovered (40% of number banded) were on the Tekapo Plain within 20 km of their initial capture sites. Immatures, however, appeared to be mainly transients. Only 10 immature and pullus harriers (9% of number banded) were subsequently recovered, and 5 of these were 80 - 850 km to the north, including three in the North Island (Table 5). No harriers from other parts of New Zealand were captured during the study period. However, a juvenile female harrier which had been banded at Lake Ferry, Wairarapa, on 1 June 1982 (D. M. Sim, pers comm.) was found dead on the Cass Delta on 19 December 1982, 470 km from the banding site.

Nesting

In the Tekapo study area harriers nested only in zones 1-3 and no nests were found on the tussock plateaux on either side of the riverbed. Nest sites were rushes or tall grass (6 nests), matagouri bushes on terrace slopes (3), and riverbed debris (2). Closest nesting neighbours were 370 - 3220 m away (average 1180 m for the two years combined). Laying occurred in October and November each year, and except for one bird which had flown by 26 December 1985, young fledged in January in both years. In the 1985 season usually two young were reared (average 2.25, range 2-3, n = 4), but in the 1986 season five successful pairs each reared three young. Of three nests found in the 1987 season, two each contained two well-grown young and the other contained two well-grown young and a small nestling.

DISCUSSION

Dietary response

Baker-Gabb (1986) found New Zealand harriers to be more diverse and flexible in their diets than Australian harriers, and they also fed more on carrion, especially sheep *(Ovis aries)* and road-killed animals. MacKenzie Basin harriers, however, specialised on rabbits. Even after rabbit poisoning, rabbits were still prominent in the diet of harriers, probably reflecting the large hunting range of individuals. In the Manawatu dune country, Baker-Gabb (1981) found resident harriers ranging over about 900 ha.

Local poisoning of rabbits did, however, result in a slight broadening of the diet of resident harriers, and in the Tekapo study area there was also a reduction in the proportion of young rabbits eaten. In both study areas, the dietary broadening comprised mainly a switch to skinks. All identified skinks were *L. nigriplantare*, which were common even on fairly bare ground (including on the plateaux), where they may have been vulnerable. The larger *L. lineoocellatum/chloronoton* were not recorded, probably because they stayed near boulders, running under them when disturbed.

Lizards (and insects) are important in the diet of several species of palearctic harrier (Schipper 1973, 1980), particularly the smaller two species: Pallid Harrier *(C. macrourus)* and Montagu's Harrier *(C. pygargus)*. Surprisingly few lizards have been recorded in the diet of harriers in other parts of New Zealand, although many birds have been. These differences are probably due to regional and seasonal differences in prey availability, skinks being particularly common in parts of the MacKenzie Basin. Similarly, the contrasting levels of predation on birds in the Tekapo and Cass study areas probably reflect the more diverse avifauna in the Cass Valley. No evidence was found of harriers preying heavily on eggs or young of native bird species in either study area.

MacKenzie Basin harriers fed little on sheep carrion, and scavenging on roadside animals was of local importance only. Cat-killed rabbits were probably more important carrion in both study areas, as Gibb *et al.* (1978) found for Wairarapa harriers. The relative importance of carrion and live prey to harriers was difficult to determine. If carrion provided the bulk of the food for Tekapo harriers, one might expect that rabbits would be more frequent in the diet when cats were most common and when harriers were least common (the latter thereby reducing competition for carasses). The opposite occurred: rabbit remains were least often found in harrier pellets in 1984-85, when harriers were scarce but cats were common (20 adult cats recorded compared with 11 in spring-summer 1985-86 and 13 in spring-summer 1986-87). In addition, remains of rabbits able to be aged in harrier pellets were mainly of young rabbits (whereas cats killed mainly large rabbits), which suggested that harriers killed most of their food themselves.

Numerical response

In the Tekapo study area, our higher rates of capturing harriers on the plateau in 1986 corresponded with increasing rabbit numbers there in 1985 and 1986. Poisoning of riverbed rabbits in 1986 may have enhanced this trend in capture rates, although our capture rates were already high on the plateau before the poisoning in the riverbed. That raptor numbers change in response to changing prey numbers is known in other species of raptor, particularly those which prey on rodent species whose populations oscillate from year to year (Galushin 1974, Newton 1979, Phelan & Robertson 1980, Hammerstrom 1984).

Galushin (1974) believed that, because raptors are more mobile than mammalian predators, raptors repopulate favourable areas quickly and so have steady reproductive outputs and more stable total populations. The situation in the MacKenzie Basin and other parts of New Zealand is probably similar. By the current means of rabbit control, areas usually only a few thousand hectares each are poisoned to different timetables. Thus, the range of a harrier (especially the more mobile juveniles) is likely to include blocks of land with differing rabbit densities. Whereas harriers responded quickly to Tekapo poisoning, numbers of feral cats and ferrets lagged for up to 6 months after poisoning, and their recolonisation of the plateau was much slower than that of harriers (RJP, unpub. data).

Despite the increase in harrier activity on the plateau in 1986, none were found nesting there. On the Tekapo Plain harriers nested mainly on the riverbed, which may have limited the number of breeding birds but clearly not the transient birds. Some adults appeared to defend territories centred on zones 1 - 3, from which intruding birds (usually immatures) were often seen being "escorted" to about the terrace edge of zone 3. This behaviour may have influenced the distribution of capture sites of immatures.

Reversed sexual dimorphism and diet

That males prey on small animals (as occurred in Cass Valley) is predicted for raptors with strong reversed sexual dimorphism (Newton 1979). Whatever the main role of reversed sexual dimorphism (see e.g. Amadon 1975, Newton 1979, Mueller 1986), it is clearly an important factor in the diets of MacKenzie Basin harriers. Likely ways for this to come about would be for males to be more manoeuvrable (and therefore able to catch small prey) and for females to be able to catch larger rabbits and defend carcasses against other harriers. Perhaps females have a competitive advantage over males in the open tussock country of the MacKenzie Basin, where small prey are scarce. This view is supported by the sex ratios of captured harriers, which favoured females in the rabbit-dominated Tekapo study area whereas in the more diverse Cass Valley, the sex ratio was approximately even. To test these ideas, it would be necessary to colour-mark individuals and make field observations of their hunting behaviour and abilities.

ACKNOWLEDGEMENTS

This work, part of a study on predators in the MacKenzie Basin, was funded by the Department of Conservation. We thank Department staff and volunteers who helped with field work, particularly A. Balance, P. Cook, B. Daniel, P. Dilks, B. Furjan, T. Hughes, and I. Southey. We are indebted to runholders J. Murray, D. Urquhart, and especially R. Allan for permitting us to work on their properties, and to D. Baker-Gabb and P. Moors for useful discussion and criticism of the manuscript.

LITERATURE CITED

AMADON, D. 1975. Why are female birds of prey larger than males ? Raptor Res. 9: 1-11.

ANON. 1968. A guide for recording rabbit sign. Wellington DSIR, Govt Printer.

BAKER-GABB, D. J. 1981. The diet of the Australasian Harrier *(Circus approximans)* in the Manawatu-Rangitikei sand country, New Zealand. Notornis 28: 241-254..

BAKER-GABB, D. J. 1986. Ecological release and behavioural and ecological flexibility in Marsh Harriers on islands. Emu 86: 71-81.

CARROLL, A. L. K. 1970. A note on measurements of the harrier *Circus approximans*. Notornis 17: 320-321.

DOUGLAS, M. J. W. 1970. Foods of harriers in a high country habitat. Notornis 17: 92-95..

GALUSHIN, V. M. 1974. Synchronous fluctuations in populations of some raptors and their prey. Ibis 116: 127-134.

GIBB, J. A.; WARD, C. P.; WARD, G. D. 1978. Natural control of a population of rabbits *Oryctolagus cuniculus* (L) for ten years in the Kourarau enclosure. Wellington: DSIR Bull. 223.

GURR, L. 1968. Communal roosting behaviour of the Australasian Harrier *Circus approximans* in New Zealand. Ibis 110: 442-447.

HAMMERSTROM, F. 1979. Effect of prey on a predator: voles and harriers. Auk 96: 370-374.

MUELLER, H. C. 1986. The evolution of reversed sexual dimorphism in owls: an empirical analysis of possible selective forces. Wilson Bull. 98: 387-406.

NEWTON, I. 1979. Population ecology of raptors. Buteo Books, Vermillion, South Dakota.

PHELAN, F. J.; ROBERTSON, R. J. 1978. Predatory responses of a raptor guild to changes in prey density. Can. J. Zool. 56: 2565-257.

PIERCE, R. J. 1983. The charadriiforms of a high country river valley. Notornis 30: 169-185.

PIERCE, R. J. 1986. Differences in susceptibility to predation between Pied and Black Stilts *(Himantopus* spp.). Auk 103: 273-280.

SCHIPPER, W. J. A. 1973. A comparison of prey selection in sympatric harriers (*Circus*) in Western Europe. Le Gerfaut 63: 17-120.

SCHIPPER, W. J. A. 1980. *Circus* species. Pages 109-137 *in* Cramp, S.; Simmons, K. E. L. (eds). Handbook of the Birds of Europe, the Middle East and North Africa, Vol 2.

RAY PIERCE, *P.O. Box 5521, Auckland;* RICHARD MALONEY, *Zoology Dept, University of Canterbury, Christchurch*

BREEDING AND SOCIAL PATTERNS OF BANDED DOTTERELS *(Charadrius bicinctus)* AT CASS RIVER

By R.J. PIERCE

ABSTRACT

The breeding of Banded Dotterels was studied in 1977-1987 at Cass River Delta, Lake Tekapo. Most birds first nested as 1-year-olds, but 1-year-olds arrived later on the breeding grounds than experienced adults. Nest site fidelity between years was high for experienced males but less for experienced females. Natal site fidelity was lower in females, which nested up to 31 km from the natal site. The birds were monogamous and usually retained the same mate for repeat clutches within a season, but most changed mates between years. Family members parted at about the time the young could fly. Sight recoveries of juveniles indicated that those which had fledged early or midway through the season subsequently migrated to Australia but late-fledging juveniles were non-migratory.

INTRODUCTION

Members of the cosmopolitan plover genus *Charadrius* are fairly homogeneous in morphology, breeding displays and voice (e.g. Cramp & Simmons 1983, Bomford 1986). They are, however, diverse in their patterns of nesting biology, particularly mating systems and fidelity to the nest site (e.g. Lessels 1984). Breeding patterns of Northern Hemisphere plovers are generally well known, but those of others, including the Banded Dotterel, have been little studied.

This paper gives details of arrival times, mate and site fidelities, post-breeding flocking and local wintering at Cass River Delta, Lake Tekapo. It is based on observations of colour-banded birds from 1977 to 1987.

STUDY AREA AND METHODS

The main study area, described previously (Pierce 1983), was the mainly stable shingle beds of the Cass River Delta (700-730 m a.s.l.). I checked for dispersing Cass Delta birds and did further banding on the middle and upper reaches of the Cass River, the Godley and Macaulay River Valleys (20 km to the north) and Tekapo River (>20 km to the south). In 1985 and 1986 several people helped me check and band dotterels throughout the MacKenzie Basin.

Dotterel nests were found mainly by watching the adult birds from a vehicle used on the many access tracks on the riverbed. I marked each nest-site with a small (<100 mm high) stone cairn about 10 m from the nest, and this was a recognisable landmark the following season. I captured adults at the nest by means of a netting drop-trap, which the bird sprang as it returned to the nest. Each bird was taken 20-30 m away from the nest site to be sexed, weighed, measured and banded. Sexes were distinguished by markings on the breast and especially the head, which are darkest in males. Each bird was given an individual colour combination: a numbered stainless steel band (size B) and 1-4 coloured PVC bands, placed on the tarsi. For example, M-RY is metal on the left and red over yellow on the right. This work disrupted nesting dotterels for no longer than 30 minutes.

Throughout the year I made frequent counts on the Cass Delta and checked all birds seen for colour bands. In the late winter and spring of four years (1979, 1983, 1984, and 1985), I spent a few hours searching for returned migrants every 2-3 days. As the dotterels tended to be in local concentrations in winter and early spring, they were easy to check for new arrivals. Even so, I would have missed many birds, especially late in the season. Because of this problem, any birds that were already nesting when I saw them first and any birds first seen after October are excluded from the analyses of arrival times of different age and sex groups.

RESULTS

Return of migrants

The earliest returning colour-banded migrants were recorded in the second half of July (Table 1). Mean arrival times of experienced birds (2 + years old) were the first week of September in 1979, 1983, and 1984, but in the second half of August in 1985. There was no significant difference in arrival times between experienced males and experienced females. One-year-old birds arrived later than experienced adults in all years.

TABLE 1 — Arrival dates of migrants in four years

Year	Earliest Arrival Date	Mean Arrival Dates		
		Experienced Males	Exerienced Females	One-year-olds
1979	21 July[1]	1 Sep (n = 20)[2]		1 Oct[3](14)
1983	No July data	5 Sep (14)	4 Sep (28)	18 Sep[3](12)
1984	17 July	6 Sep (17)	2 Sep (23)	Few Data
1985	19 July	18 Aug (27)	25 Aug (49)	31 Aug (13)

Notes: 1. Returned from Australia (Dann & Pierce 1979).
2. Sample sizes are given in parentheses. Male and female data pooled for 1979.
3. Signaficantly later mean arrival dates than those of experienced birds in the same year ($p < 0.05$, Student's t-test).

There was no evidence that experienced breeders missed breeding seasons: on only 11 (3%) occasions were birds missed one year but seen in a later year ($n = 382$ "bird years"), and these may just have been birds I missed. Not all 1-year-old birds were found on the breeding grounds (Table 2). Of surviving chicks, the return rate (76%) at 1-year old is significantly less than the x^2 expected value of 100% ($x^2 = 4.9$, 1 d. f., $p < 0.05$, $n = 89$). Proportionately more colour-banded males than females were seen as 1-year-olds on the Cass Delta ($x^2 = 4.62$, 1 d.f., $p < 0.05$, $n = 86$). All returning 1-year-olds that were closely monitored did nest or attempt to nest during that season.

TABLE 2 — Age at which birds colour-banded as chicks were first recorded back at Cass Delta.

		Age in years				
Sex	N	1	2	3	4	5
Male	54	41	9	1	0	3
Female	32	25	5	2	0	0
Unknown	3	2	0	1	0	0
Total	89	68	14	4	0	3

Dispersal for nesting

Arriving migrants in July and August joined the groups of birds that had overwintered. During cold periods and while snow was lying, the birds foraged mostly on lakeshore mud or along river channels, where some individuals maintained small feeding territories up to 40 m in length and for up to 5 weeks at a time. In milder weather, most birds foraged on short-turfed pasture, particularly in wet areas. Included among these delta concentrations were several birds whose nesting areas were up to 10 km further upstream in the Cass Valley. During August and September, increasing numbers of birds began to visit and eventually occupied the breeding grounds, which mainly comprised regenerating herbfields on or adjacent to the riverbed.

Usually the males occupied the breeding grounds first, establishing territories often in the absence of females. The females tended to continue foraging on the pasture or on the mudflats, giving rise to local variations in the sex ratio. During snowfalls and ensuing snow-cover, prebreeding birds or failed nesters often returned to the lakeshore or river edges. While nesting, off-duty dotterels usually foraged within 200 m of the nest site, but many (and failed nesters) returned to the pasture where they foraged in loose flocks up to 2 km from their nest sites.

Possibly the highest density of nesting pairs seen on the riverbed was in November 1985: on the central part of the north bed of the delta I found 17 pairs nesting in an area measuring 180 × 700 m, giving an overall density of 1.35 pairs per hectare. Adults did some (probably most) of their feeding in those territories.

Mate fidelity

Banded Dotterels are monogamous. On rare occasions, additional males (Oreti River 1985, M. Barlow, pers. comm.; Waipawa River 1986, pers. obs.) or females (Ruamahanga River 1987, pers. obs.) share nest duties.

At Cass River there were 18 colour-banded pairs in which both members were known to be alive the following year. Eight of these pairs renested together, and ten nested separately. For repeat clutches within a season, however, the pair bond was usually retained (Table 3a). In most cases in which interseasonal bonds were broken, the female had settled farther away from the previous season's nest site than the male had (Table 3b).

TABLE 3 — Pair bond retention and corresponding shifts in rest sites

A. Pair bond retention

	Number Examined	Number Retained	Number Separated
Interyear	18	8	10
Repeat clutches	10	8	2

B. Distances of nest-site shifts between years by birds of known pair bonds

	Number Measured	Average Shift (m)	Range (m)
Retained pairs	6	51	18 - 120
Males in separated pairs	8	44	5 - 200
Females in separated pairs	8	270	45 - 400

Nesting site fidelity

Experienced nesters had a very high site fidelity. Of 360 bird-years, in only two had birds shifted more than 1 km from the previous season's nest site. Precise distances between interyear nest sites were found for a random sample of 62 adults (Table 4). For experienced males this distance averaged 42 m, but for females it averaged more than 5 times this value. The value for females is increased greatly by one that shifted 6.2 km to the middle reaches of the Cass Valley three seasons after if had been banded. (This bird was recaptured to confirm its identity from the band number.) Even with this exceptional record excluded, the average shift (126 m) of females is still significantly greater.

TABLE 4 — Annual shifts in nest site location

Age Group	Distance Shifted (m) N	Mean	Range	T-Test (all p < 0.05)
1. Experienced males	13	42	5 - 200	With 2: t = 2.62
2. Experienced females	49	245	0 - 6200	
3. Total experienced	62	202	0 - 6200	With 6: t = 2.44
4. One-year males	24	1170	75 - 6100	With 5: t = 2.22
5. One-year females	16	5150	100 - 30700	
6. Total one-year-olds	40	2030	75 - 30700	

For repeat clutches, the distance from first nest to second nest ranged from 0 m (once in same nest) to 15 km (a 1-year-old female renesting in the Godley Valley). Excluding the two greatest shifts (15 km and 2.16 km), all shifts were less than 110 m (n = 9 for males and females combined).

Natal site fidelity

One-year-old birds nested on average 2.03 km from their natal sites (n = 40 for males and females combined). Only three of these 40 birds nested within 150 m of their natal sites, one of which was a female nesting with her male parent of the previous season. As in experienced birds, male 1-year-olds were more philopatric than females, males returning on average 4-5 times closer to their natal area (Table 4). Some 1-year females nested considerable distances away, including three on other riverbeds up to 31 km away (Fig. 1). A fourth 1-year-old female was found on the bed of the Macaulay River (19 km to the north) during the breeding season, but it was not nesting at that time. Once a 1-year-old chose an area for nesting, however, it returned to that vicinity in subsequent years.

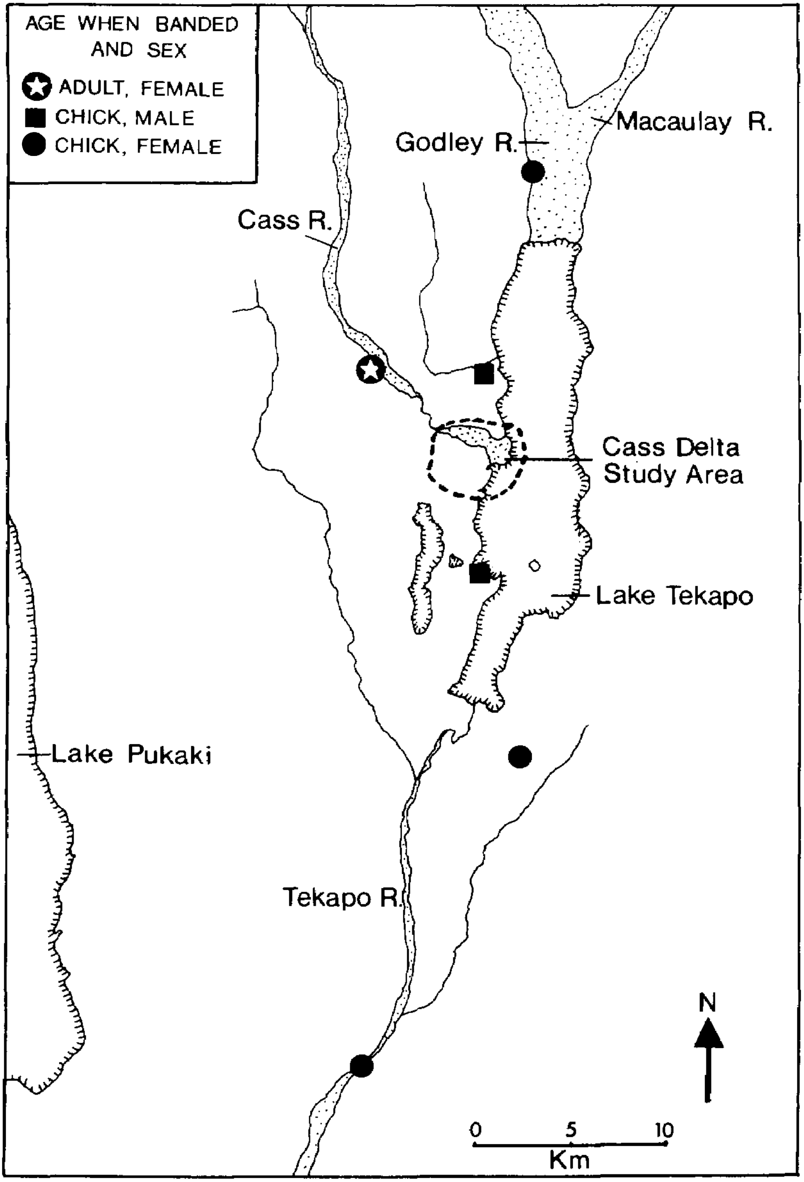


FIGURE 1 — Location of study area and of nest sites of birds which have left the delta

With their wide dispersal from their natal areas, 1-year-olds are colonisers of new areas. For example, stabilisation of the south bed in 1979 and subsequent colonisation by mat plants (Pierce 1983) has improved conditions for dotterels there. To date (1987 season), four of the five colour-banded dotterels that have colonised this bed have been 1-year-olds. (In any given year 1-year-olds account for less than 20% of colour-banded birds on the Cass Delta.)

Nesting period and renesting

Laying extended from early September to December, and Bomford (1988) found one nest in August. In the cold early spring of 1986, nesting pairs were concentrated along the main river channels where mayflies were abundant. Included among these pairs were a few colour-banded 1-year-olds nesting or attempting to nest for the first time, as well as many experienced birds which usually nested on the adjacent herbfields. The nests of these regular river-flanking pairs were closer to water then in the previous spring ($\bar{x}$ = c.120 m in 1985, $\bar{x}$ = 22 m in 1986, n = 5 pairs).

Late-nesting adults in all years were often moulting, the earliest being recorded on 13 November 1987. Wing moult was recorded in 9 (12%) of 73 incubating adults (both sexes) in November, 4 out of 9 adults in December and 2 out of 2 in January.

If a pair of dotterels lost eggs or downy chicks, they usually renested within a month. One female produced four unsuccessful clutches in one season (each of three eggs), but most pairs were successful with the first or second clutch. Renesting after the loss of older chicks was recorded for several pairs after a heavy snowfall in October 1982 (Pierce 1983). In 1984 I recorded one case of apparent double brooding: on 15 September female WYR-M was incubating three eggs, two of which hatched between 9 and 13 October (the third egg being infertile), and one juvenile was flying by 21 November: on 10 December WYR-M was found with another three-egg nest, but this was preyed on between 18 and 24 December. I do not know whether the same male was at both nests.

Chicks

Although they are mobile within a few hours of hatching, chicks usually stayed within 200 m of their natal site until they could fly. Of 76 recaptures of chicks from known nests, only five were more than 500 m from the nest site. On two of these occasions, the chicks were nearly flying and had apparently been abandoned by their parents, a not unusual event on the Cass Delta, especially late in the season. As with adults, invertebrates were the main food, but in good fruiting years, berries of *Muehlenbeckia, Coprosma pumila* and *Pimelea* sp. were also taken.

Post-breeding dispersal

Family members appeared to part company usually with in 2 weeks of the young flying. Colour-banded members of a family (including siblings) were subsequently never seen together again that season. They joined loose daytime flocks of up to 150 dotterels and foraged on the riverbed (especially near the channels of water) and also at drying-up ponds which had been little used by dotterels during the breeding period. Riverbed flocks comprised almost entirely adults, whereas flocks at flooded pasture and pools contained high proportions of juveniles (Table 5). This habitat partitioning was also noted in other parts of the MacKenzie Basin and in coastal South Canterbury.

TABLE 5 — Number and percentage of juveniles in post-breeding dotterel flocks in the three preferred habitats on the Cass Delta

	Herbfield		Riverbed		Ponds and Saturated Pasture		X^2 Value, (all p < 0.001)
Date	N	J	N	J	N	J	
20 Jan 1986	54	6 (11)	65	5 (8)	34	31 (91)	64.8
08 Jan 1987	56	5 (9)	65	6 (9)	59	54 (92)	78.4
19 Feb 1987	32	1 (3)	140	10 (14)	26	18 (69)	61.1

Note: N = number of dotterels seen; J = number of juveniles, percentage in parentheses.

From December to at least late February, most Cass adults (which were moulting) and many juveniles were in flocks within 10 km of the Cass Delta. Compared with prebreeding flocks, the flocks of post-breeding birds were more widespread and departure was very protracted, extending from December to at least late March. During this period some adults, and especially juveniles, were found in other parts of the MacKenzie Basin (up to 65 km from the Cass Delta) and at several coastal areas around the South Island.

Overwintering

Despite marked differences in the severity of winters, numbers of birds wintering around the shores of Lake Tekapo were fairly similar (100-200) from year to year, although counts during the 1980s tended to be higher than those of the 1970s. About equal numbers of males and females overwintered around Lake Tekapo. Once a juvenile had wintered in the Tekapo area, it would do the same in successive years, and the very cold winter in 1986 did not deter regular winterers (Table 6).

TABLE 6 — Wintering of Cass River birds at Lake Tekapo

				Year and Mean Winter Temp. (°C)			
Bird	Breeding Season in Which Banded	Age	Sex	1984	1985	1986	1987
				3.7	2.9	2.2	-
WM-R	1983	Ad	F	C	C	C	C
WM-RY	1983	Ad	F	C	C	C	x
WM-WR	1983	Ad	M	C	C	C	C
BM-YRW	1983	Juv	F	C	C	x	x
RYB-M	1984	Ad	F	-	G	x	x
MW-WB	1984	Juv	M	-	G	G	C
MW-YG	1984	Juv	F	-	C	C	-

Note: C = Cass Delta, G = Godley Delta, x = not seen, "mean winter temp." = mean daily air temperatures for June-August at Lake Tekapo.

Whether a bird was sedentary or became migratory seemed to depend on when it fledged (Fig. 2). Thus, all winter sightings of chicks which had fledged in November-December were in Australia (the main destination of MacKenzie Basin birds, unpub. data), whereas late-fledging chicks wintered locally (x^2 = 13.1, $p < 0.01$, sedentary behaviour by month). There was only one post-breeding sighting of offspring from these regular winterers: the November 1983 offspring of WM-R was found by K.F. Hughey at Clutha

Lagoon in coastal Otago in February and March 1985. We did not find its wintering area, although I am certain it did not winter at Lake Tekapo.

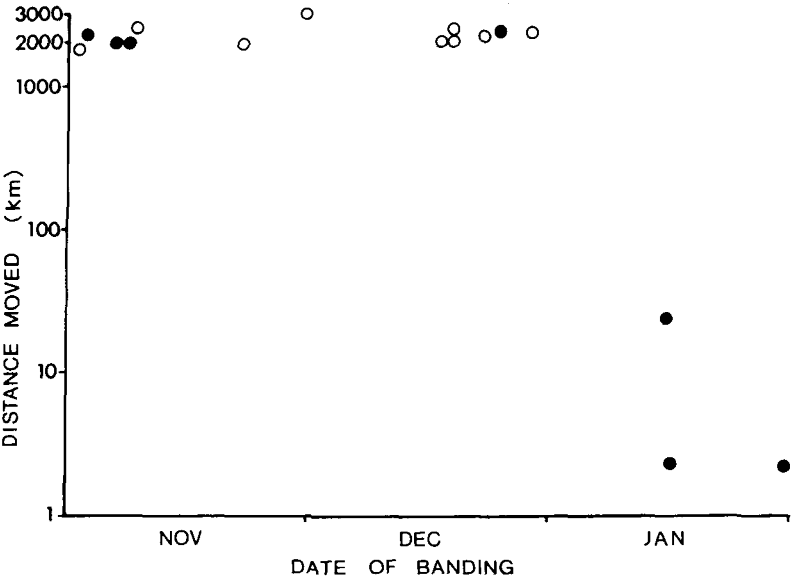


FIGURE 2 — The relationship between dates of banding of juvenile dotterels on the Cass Delta and the distances they moved to the wintering grounds. Closed circles represent sightings in their first year (± subsequent years); open circles represent sightings in second or later years only.

DISCUSSION

First breeding and migration

The age of first breeding in species of small plover varies from one to two or more years (Cramp & Simmons 1983). Breeding by most Banded Dotterels in their first year is in keeping with their relatively high productivity and low life expectancy (in prep.)

The late arrival of 1-year-olds at the breeding grounds concurs with observations on the Banded Dotterel wintering grounds in south-eastern Australia, where juveniles deposit premigratory fat later than adults do (Barter & Minton 1987). The latest sighting in any year of a colour-banded bird in Australia was of a 1-year-old Godley River bird in south-eastern Tasmania on 21 September 1986 (E. Woehler, pers. comm.). Very few Banded Dotterels spend the summer in Australia, however. My not finding some colour-banded birds in their first breeding season may be due to their brief appearances at the breeding grounds in their first season, rather than their not having returned at all.

Migratory and sedentary behaviour among partial migrants is thought to be under genetic control (e.g Berthold 1984). It seems, however, that this genetic base can be modified by other factors, including the timing of fledging. Thus, late-fledging passerines (e.g. Adriaensen 1987) and Eurasian

Golden Plovers *(Pluvialis apricaria)* (Townshend 1975) migrated farther than early fledglings. The reverse was true for Cass River dotterels, in which late-fledging birds were sedentary. The development of migratory behaviour seems to depend on the time available for juvenile dotterels to deposit the fat they need for migration, late-fledging birds apparently not having enough time.

In the Golden Plover study, early-fledging birds were sedentary because they could use the prime local feeding areas, where they became dominants, thereby forcing the late-fledging birds to migrate (Townshend 1985). An important difference between the Golden Plover and Banded Dotterel studies is that the Golden Plover had dependable food locally, whereas at Lake Tekapo the food supply was undependable, fluctuating greatly between seasons and years (Pierce 1983, unpub. data). In addition, the dispersing Golden Plover were able to travel in "leap-frog" fashion along a semicontinuous coastline, food being available at frequent intervals, whereas the trans-Tasman migration of dotterels has to be a single flight of about 2000 km.

At present I cannot say whether one of the two wintering alternatives of Banded Dotterels is more adaptive, although survival data indicate a trend towards early-fledging juveniles having highest survival (unpub. data). Age-related migration patterns are currently being examined for Banded Dotterels in other parts of New Zealand.

Site fidelity

In the MacKenzie Basin, Banded Dotterels avoid inbreeding by the young birds (especially females) having low site fidelity. Males nest closer to their natal sites than females do and return earlier and nearer to the previous season's nest site. The early return of males to the breeding ground is usual for migratory species (Gauthreaux 1978). Greenwood (1980) proposed that the avian tendency for males to be more site specific than females is caused by the advantage of site familiarity, which in most species is more important to males than females. The dominant role of male Banded Dotterels in establishing and maintaining territories (e.g. Bomford 1988) is consistent with Greenwood's hypothesis. One wader species in which females are known to have greater site fidelity than males is the polyandrous Spotted Sandpiper *(Tringa macularia)*, in which many of the roles of the sexes are reversed (Oring & Lank 1982).

Site fidelity is high in many other *Charadrius* plovers, including Ringed Plovers *(C. hiaticula)* (Laven 1940, Bub 1962), Kentish Plovers *(C. a. alexandrinus)* (Rittinghaus 1956), Mountain Plovers *(C. montanus)* (Graul 1973), Kildeers *(C. vociferus)* (Lenington & Mace 1975), and Piping Plovers *(C. melodus)*. As with Banded Dotterels, male Piping Plovers have a higher site fidelity than females (Wilcox 1959). Two notable exceptions are the Eurasian Dotterel *(C. morinellus)* (Cramp & Simmons 1983) and Little Ringed Plover *(C. dubius)*. In the latter species, Glutz *et al.* (1975) found that first-time breeders settled up to 250 km (mean 33.2 km) from the natal area (in Germany), and that adults settled up to 102 km (mean 5.5 km) from the previous season's site.

On the Cass River, the maximum distance found between the natal area of Banded Dotterels and their area of first nesting was only 31 km. Recent work by the Banded Dotterel Study Group has revealed several instances of 1-year-olds and experienced birds nesting up to 23.5 km from their original banding sites. The two greatest shifts have been of experienced birds banded near Alexandra in Central Otago: a 1985 male renesting the same season 23.5 km away on the summit of Old Man Range; and a 1985 or 1986 female nesting 22 km away near Cromwell in 1987 (M. Child, pers. comm). Most of the shifts have been from small pockets of changing habitat, including areas in which the growth of tall grass sometimes prevents nesting. By contrast, dotterel habitat on the Cass Delta is extensive and mainly stable from year to year, and so the dotterels do not need to make major changes in nest location. If strong site fidelity is usual throughout New Zealand, the Banded Dotterel may well vary morphologically on the mainland. This aspect is currently being examined.

Mating systems and pair bonds

The genus *Charadrius* has a wide range of mating patterns, from multiple clutches reared separately by the male and female in the Mountain Plover (Graul 1973), through frequent sequential polyandry in the Kentish Plover (Lessels 1984) and the Eurasian Dotterel (Nethersole-Thompson 1973), to monogamy with or without multiple brooding in the Ringed Plover (Pienkowski 1984), the Piping Plover (Cairns 1982) and the Kildeer (Lenington 1980). Banded Dotterels are in the last category, being mainly monogamous and single brooded.

Nest "helpers", seen on three New Zealand rivers, have been recorded in several *Charadrius* species (Cramp & Simmons 1983). In the apparent double brooding by the female M-WYR, the males at the two nests were not banded and so may not have been the same bird. Polyandry seems unlikely because, in the polyandrous Kentish Plover, the female deserts the brood soon after it hatches (Lessels 1984). Female M-WYR attended the chick from the first brood until it could fly and then renested, and so the incident was probably genuine double brooding.

A feature of all *Charadrius* plovers studied is that the pair bond is kept for the breeding season only. Usually each bird has a new mate the following year. Exceptionally, Ringed and Kentish Plovers may keep their pair bonds for several years, especially in unchanging habitats (Cramp & Simmons 1983). Banded Dotterels have kept their pair bonds for at least three seasons on pasture near Mayfield (D. Geddes, pers. comm.) and on the ocean beach at the mouth of the Rakaia River (K. Hughey, pers. comm.), but at the Cass Delta mate retention is low. This is surprising because the habitat changes little and males move little between sites from year to year. However, if many unmated, territorial males are spread over a large area (as is usual at the Cass Delta), competition for female partners would be high. Thus a male is likely to have the same mate in successive seasons only by chance, depending largely on how soon the female arrives after the male's initial displays on territory. Some useful comparisons could be made with areas containing fewer dotterels than the Cass Delta and in areas where habitat changes markedly from year to year.

ACKNOWLEDGEMENTS

Help in banding birds was provided by many people, particularly M. Child, the late P. Child, P. Dann, P. Dilks, K. Hughey, C. Minton, R. Maloney, and R. Veitch. I thank M. Bomford for permitting me to use her banding data from 1977. Bands were provided by the Banding Office, Department of Conservation. During 1984-86 data were collected in conjunction with a Department of Conservation study on carnivorous mammals. Many useful comments on the manuscript were provided by K. Hughey and R. Williamson.

LITERATURE CITED

ADRIAENSEN, F. 1987. Differences in migratory behaviour between early and late brood nestlings of the Robin *Erithacus rubecula*. Ibis 129: 263-267.

BARTER, M.; MINTON, C. 1987. Biometrics, moult and migration of Double-banded Plovers *Charadrius bicinctus* spending the non-breeding season in Victoria. The Stilt 10: 9-14.

BERTHOLD, P. 1984. The control of partial migration in birds: a review. The Ring 10: 253-265.

BOMFORD, M. 1986. Breeding displays and calls of the Banded Dotterel *(Charadrius bicinctus)*. Notornis 33: 219-232.

BOMFORD, M. 1988. Breeding of the Banded Dotterel, *Charadrius bicinctus*, on the Cass River Delta, Canterbury. Notornis 35: 9-14.

BUB, H. 1962. Planberingungen am Sandregenpfeifer *(Charadrius hiaticula)*. J. Orn. 103: 243-249.

CAIRNS, W. E. 1982. Biology and behaviour of breeding Piping Plovers. Wilson Bull. 94: 531-545.

CRAMP, S.; SIMMONS, K. E. L. 1983. The Birds of the Western Palearctic, Vol 3. Oxford. Oxford University Press.

DANN, P.; PIERCE, R. J. 1979. Australian sight recovery of a colour-banded Dotterel. Notornis 26: 368.

GAUTHREAUX, S. A. 1978. The ecological significance of behavioural dominance. Pages 17-54 *in* Bateson, P. P. G.; Kloper, P. H. (eds). Perspectives in Ethology. Vol. 3. Plenum, New York.

GLUTZ VON BLOTZHEIM, U. N.; BAUER, K. M.; BEZEL, E. 1975. Handbuch der Vogel Mitteleuropas. Vol.6. Akademische Verlagsgesellschaft.

GRAUL, W. D. 1975. Breeding biology of the Mountain Plover. Wilson Bull. 87: 6-31.

GREENWOOD, P. J. 1980. Mating systems, philopatry and dispersal in birds and mammals. Anim. Behav. 28: 1140-1162.

LAVEN, H. 1940. Beitrage zur Biologie des Sandregenpfeifers *(Charadrius hiaticula* L.). J. Orn. 88: 183-287.

LENINGTON, S. 1980. Bi-parental care in Kildeer: an adaptive hypothesis. Wilson Bull. 92: 8-20.

LENINGTON, S.; MACE, T. 1975. Mate fidelity and nesting site tenacity in the Kildeer. Auk 92: 149-151.

LESSELS, C. M. 1984. The mating systems of Kentish Plovers *Charadrius alexandrinus*. Ibis 126: 474-483.

NETHERSOLE-THOMPSON, D. 1973. The Dotterel. London: Collins.

ORING, L.; LANK, D. 1982. Sexual selection, arrival times, philopatry and site fidelity in the polyandrous Spotted Sandpiper. Behav. Ecol. Sociobiol. 10: 185-192.

PIENKOWSKI, M. W. 1984. Breeding biology and population dynamics of Ringed Plovers *Charadrius hiaticula* in Britain and Greenland: nest predation as a possible factor limiting breeding and timing of breeding. J. Zool. Lond. 202: 83-114.

PIERCE, R. J. 1983. The charadriiforms of a high country river valley. Notornis 30: 169-185.

RITTINGHAUS, H. 1956. Unterschungen am Seeregenpfeifer *(Charadrius alexandrinus* L.) auf der Insel Oldeoog. J. Ornithol. 97: 117-155.

TOWNSHEND, D. J. 1985. Decisions for a lifetime: establishment of spatial defence and movement patterns by juvenile Grey Plovers *(Pluvialis squatarola)*. J. Anim. Ecol. 54: 267-274.

WILCOX L. R. 1959. A twenty year banding study of the Piping Plover. Auk 76. 129-158.

RAY PIERCE, *P.O. Box 5521, Auckland*

SHORT NOTE

The status of the Red-capped Dotterel in New Zealand

The Red-capped Dotterel *(Charadrius ruficapillus)* is a small (140-165 mm) dotterel native to Australia where it occurs on a variety of mainly coastal shores but also inland (Pizzey & Doyle 1980). Its status in New Zealand has varied and has remained uncertain.

Historical records

As McKenzie (1980) observed, the Red-capped Dotterel has had a curiously inconclusive history in New Zealand. First recorded near Waikanae in 1878, the next record was not until 1947-50 when a single female bred with a Banded Dotterel *(C. bicinctus)* on the Ashley River in North Canterbury (Oliver 1955). Between 1955 and 1975 further sightings were made on or near the Ashley River, one bird was seen at Lake Tuakitoto in South Otago and several sightings, including one of two birds, were made near Auckland (McKenzie 1980). McKenzie wondered whether these northern sightings were of stragglers from Australia or of birds among migrating Banded Dotterels from Canterbury.

During the 1960s and 1970s, Davis (1980) made several sightings of breeding and non-breeding birds on three North Canterbury rivers: the Ashley, Waipara (Figure 1) and Leader. In 1966 she recorded eight Red-capped Dotterels on the Ashley River. The most recent record by Davis was of an adult pair at the mouth of the Ashley River in 1978. A pair attempted breeding on the Ashley River in the 1979-80 breeding season (Howell, pers. comm. *in* O'Donnell & Moore 1983), and Sagar (1982) found a male at Lake Ellesmere (Waihora) on 24 January 1981.

Recent surveys

The Wildlife Service surveyed the lower Ashley River in October 1980 (Moore 1980) but found no Red-capped Dotterels. Over the past few breeding seasons I have walked most of the lower Waipara River, and in December 1986, Paul Pierson, Peter Tillson and I surveyed the Leader River. Since 1983 I have covered most of the lower Ashley River, in most places several times. I have made many trips to the Ashley Estuary, as have others, especially S. Moore of the former Wildlife Service. We have seen no Red-capped Dotterels.

On 22-23 November 1987, staff of the Department of Conservation and volunteers systematically surveyed the lower 10 km of the Ashley River, the lower Kowai River and the lower Waipara River. All of the coastal estuaries and ponds and much of the wide beaches between the Waimakariri and Waipara Rivers were also surveyed (Hughey 1987). Red-capped Dotterels were not found. Furthermore, none has been seen near Auckland since 1975.

DISCUSSION

Red-capped Dotterels seem to have bred in New Zealand during three decades from 1950 to 1980. A small population was apparently established on the Ashley River with birds also recorded on the Waipara and Leader rivers. Non-breeding birds were recorded at the Ashley Estuary and, on

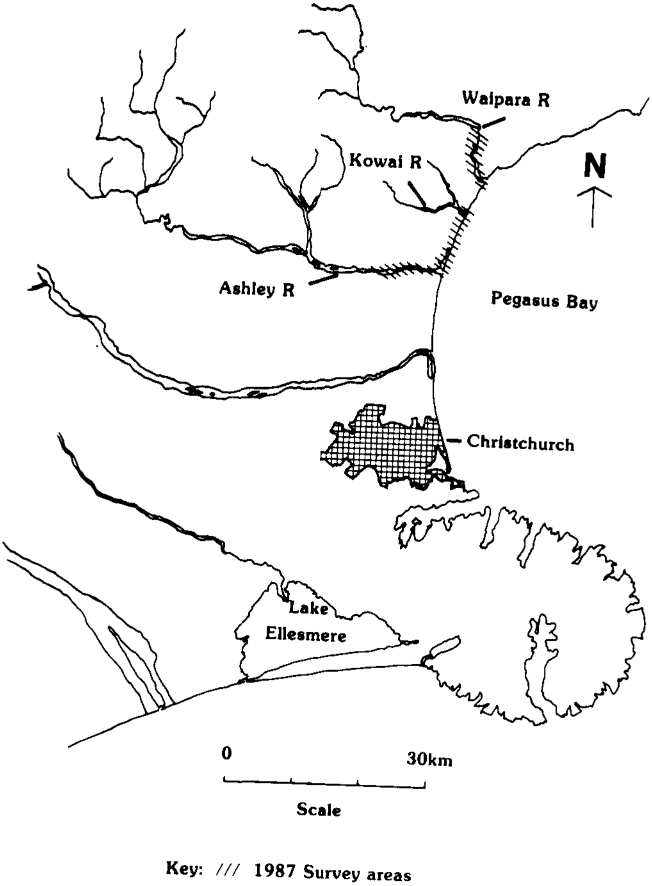


Figure 1. — Study areas

occasions, near Auckland. The last breeding record was from the Ashley River in 1979 and the last non-breeding records were in 1975 for Auckland and 1981 for Lake Ellesmere (Waihora). The disappearance of this species from previously known breeding sites seems to have been confirmed by the intensive 1986-87 surveys.

Why Red-capped Dotterels have died out in New Zealand is difficult to explain. Similar events have occurred for several other species, e.g. Nankeen Kestrel *(Falco cenchroides)* and Red-necked Avocet *(Recurvirostra novaehollandiae)*. Habitat, climate, food supply or competition may be contributing factors in these arrival, establishment and extinction cycles. In Australia Red-capped Dotterels breed and feed along shore lines, around lake shores and estuary margins; almost always on a sand substrate. Superficially similar habitats are abundant in New Zealand. Many Red-capped Dotterels occur in Tasmania ata similar latitude with a similar climate to many parts of New Zealand. These conditions seem to support similar invertebrate fauna, and so food supply is not likely to be a reason for extinction.

Although sightings around Auckland harbours had been irregular they nevertheless occurred during the period of establishment and breeding in North Canterbury. That none have been seen in the north since 1975, only six years before the final Canterbury record, makes McKenzie's (1980) question about the Auckland record very interesting. Davis (1980) suggested that birds arrived on the riverbeds in late winter and stayed until late November. All Auckland sightings were in the December-March period (McKenzie 1980). It seems likely that these birds had migrated north from Canterbury. The second part of McKenzie's proposition seems unlikely, in the light of recent study of Banded Dotterels. So far, of more than 200 Banded Dotterels colour banded on the lower Ashley River only four have been reported from the North Island. Most have been seen at Lake Ellesmere (Waihora), followed by Australia (Hughey, unpub. data). Movement north with flocks of Banded Dotterels therefore seems unlikely. However, all of the Wrybills *(Anarhynchus frontalis)* nesting on the Ashley River migrate to the North Island (Hughey, unpub. data).

ACKNOWLEDGEMENTS

I thank the Department of Conservation staff and volunteers for assistance in the 1986-87 river surveys and for previous assistance on related work which has subsequently contributed to this paper. I also thank Rodney Hide and Ray Pierce for helpful criticism and Olga Cattanach for typing the manuscript.

REFERENCES

DAVIS, M. M. 1982. Red-capped Dotterel in North Canterbury. Notornis 27: 367-368.

HUGHEY, K. F. D. 1987. Bird surveys of the lower Ashley, Kowai and Waipara rivers, and of adjacent coastal areas, 1987. Unpubl. Report. Department of Conservation, Christchurch.

McKENZIE, H. R. 1980. Some Red-capped Dotterel records. Notornis 27: 291-292.

MOORE, S. G. M. 1980. Wildlife Survey of the Ashley River. Unpubl. Report. N.Z. Wildlife Service, Department of Internal Affairs, Christchurch.

O'DONNELL, C. F. J.; MOORE, S. M. 1983. The Wildlife and Conservation of Braided Rivers in Canterbury. Fauna Survey Unit Report No. 33. N.Z. Wildlife Service, Department of Internal Affairs, Christchurch.

OLIVER, W. R. B. 1955. New Zealand Birds. Wellington: Reed.

PIZZEY, G.; DOYLE, R. 1980. A Field Guide to the Birds of Australia. Sydney: Collins.

SAGAR, P. M. 1982. Red-capped Dotterel. In: Classified Summarised Notes. Notornis 29: 49-74.

K. F. D. HUGHEY, *Department of Conservation, Private Bag, Christchurch*

CAVITY NESTING IN STITCHBIRDS AND THE USE OF ARTIFICIAL NEST SITES

By GRETCHEN RASCH

ABSTRACT

Cavity nesting by Stitchbirds *(Notiomystis cincta)* was studied on Little Barrier Island by adding artificial nest sites (boxes) in a breeding habitat. The addition of boxes was a test of the theory that the number of breeding pairs of cavity nesting species is limited by the availability of suitable holes for nest sites. Site limitation is also said to prevent males of these species from taking more than one mate. This theory was tested by placing some boxes close to natural nest sites and other boxes. Results showed that the number of breeding Stitchbirds was not necessarily limited by the availability of sites, and that lack of sites did not restrict male birds to monogamy. The boxes could be a useful management tool for enhancing this rare species.

INTRODUCTION

The Stitchbird *(Notiomystis cincta)* is one of only two species of honeyeater (family Meliphagidae) to use tree cavities as nest sites. (The other species is the nearly extinct Hawaiian honeyeater, the Kauai O'o *Moho braccatus.*) This habit of nesting in tree holes is interesting from both evolutionary and ecological viewpoints (Rasch 1985b). Furthermore, this behaviour can be manipulated for the benefit of the species by the use of artificial nest sites. With this in mind, I began an experiment in 1984 to study cavity-nesting behaviour in Stitchbirds and the effect of adding nest boxes.

The first objective of the experiment was to develop an artificial nest box which Stitchbirds would accept. If Stitchbirds would use them, artificial nest sites could be a useful management tool for establishing Stitchbirds on other sites, especially those with young, regenerating forest, which often lacks trees with natural cavities.

Artificially increasing the number of breeding pairs of Stitchbirds was the second objective. I wanted to test the theory that the breeding density of cavity-nesting species is limited by the availability of nest sites. The survival of nestlings is significantly greater in species that use cavity nests than in species that use open nests (Nice 1957, Lack 1968). Evolutionary theory suggests that birds should prefer cavity nests if using these sites increases their breeding success. Yet open-nesting species generally outnumber cavity-nesting species in forests. It has been said that the breeding density (i.e. nesting pairs per hectare) is limited by the number of suitable cavities available, and therefore open nesting allows greater numbers to breed (von Haartman 1957, van Balen *et al.* 1982). In a large number of studies the addition of artificial nest sites to breeding areas has resulted in increases in the breeding density of cavity nesters, thus showing that site limitation often occurs (von Haartman 1957, Enemar & Sjostrand 1972, Slagsvold 1975, Brush 1983, Herlugson 1983, Nilsson 1984). Often the increase is quite dramatic. Hogstadt (1975) reported a ten-fold increase in the number of cavity-nesting pairs per hectare after nest boxes were added. If Stitchbirds are limited by the availability of nest sites, the addition of nest boxes should increase the number of breeding pairs.

NOTORNIS 36: 27-36 (1989)

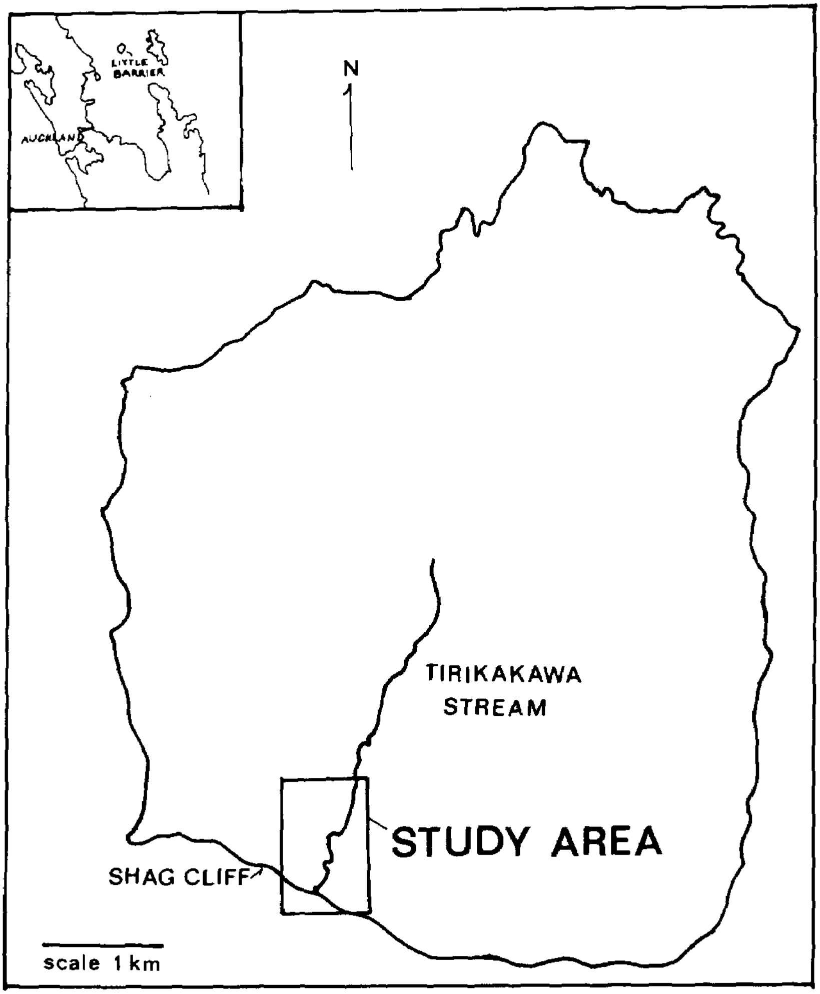


FIGURE 1 — *Location of the study site in the Tirikakawa Valley, Little Barrier Island*

The third objective was to find out whether the normally monogamous Stitchbird could become polygamous (take more than one mate), given the right conditions. The theory of natural selection states that individuals increase their chances of genetic survival by maximising their reproductive output (Alcock 1984). That is, the more offspring an animal has, the greater the possibility of its genetic line being represented in future generations. Therefore multiple matings (polygamy) is one way for an individual to promote the survival of its genotype.

As members of the opposite sex are limited in number, there is competition among members of the same sex for potential mates (Krebs & Davies 1981). In species in which only female birds incubate the eggs, males have a greater opportunity to take extra mates. Males are monogamous only when they are prevented from taking additional mates because competition is too great, or because survival of the clutch depends on both parents caring for the young (Emlen & Oring 1977). In cavity-nesting species, where owning a nest hole is a prerequisite to mating, monogamy may result because males can defend only one nest site at a time if nest sites are limited (Wittenberger & Tilson 1980). Only male Stitchbirds were considered in this experiment because the females are committed to nest building, laying, and incubation (Rasch 1985a). My hypothesis was that, if nest boxes were added close to natural sites (and to one another), male Stitchbirds could defend more than one site and therefore take more than one mate.

METHODS

Stitchbirds live only on Little Barrier Island (36° 12'S, 175° 7'E) in the Hauraki Gulf, except for small numbers recently released on Hen, Cuvier, and Kapiti Islands. The study site on Little Barrier included the Tirikakawa Valley and the Shag Cliff area (Figure 1). Elevation was from sea level to 150 m a.s.l. The study site was divided into three areas (Figure 2). Area I included the Shag Cliff and the first 250 m (from the valley mouth, upstream) of the Tirikakawa Valley. Forest cover of this 3 ha area was predominantly kanuka (*Kunzea ericoides*) forest. Area II was a 2.8 ha area over the next 250-550 m upstream from Area I. This was a transition zone between kanuka and rata/tawa (*Metrosideros* spp./*Beilschmiedia tawa*) forest. Area III was 550-1300 m from the valley mouth and covered 5.5 ha. The canopy in this area was rata/tawa.

Puriri (*Vitex lucens*) and pohutukawa (*Metrosideros excelsa*) trees grew along the cliff and the stream. Stitchbirds most often use cavities in these two species as nest sites. Stitchbirds are secondary cavity nesters. That is, they use already existing holes in old or diseased trees and do not excavate new ones. The birds often re-use the nests in following years (Rasch 1985a).

When I began the nest box experiment, I knew the locations of eight natural nest sites in Area I and Area III. Three nest sites were in Area I and four were in Area III. During the experiment I found two more natural sites (site B and site C) in Area I. No natural nest sites were found in Area II. Nest sites were found by careful observation of Stitchbird behaviour. Males conspicuously defend nest sites with loud singing to attract mates, and are in constant attention at the site during incubation. During the nestling period, parent birds feed the young 2-7 times per hour and can be observed as they enter and leave the nest (Rasch 1985a).

Twenty nest boxes were constructed to measurements made from natural sites (Figure 3). One feature of Stitchbird nests is that the actual nest cavity is an average distance of 280 mm above the outside entrance. This "tunnel" from entrance to nest was incorporated into the nest box design. I hoped that this would discourage other cavity-nesters on Little Barrier from using the boxes; the Saddleback *(Philesturnus carunculatus)*, Rifleman (*Acanthisitta*

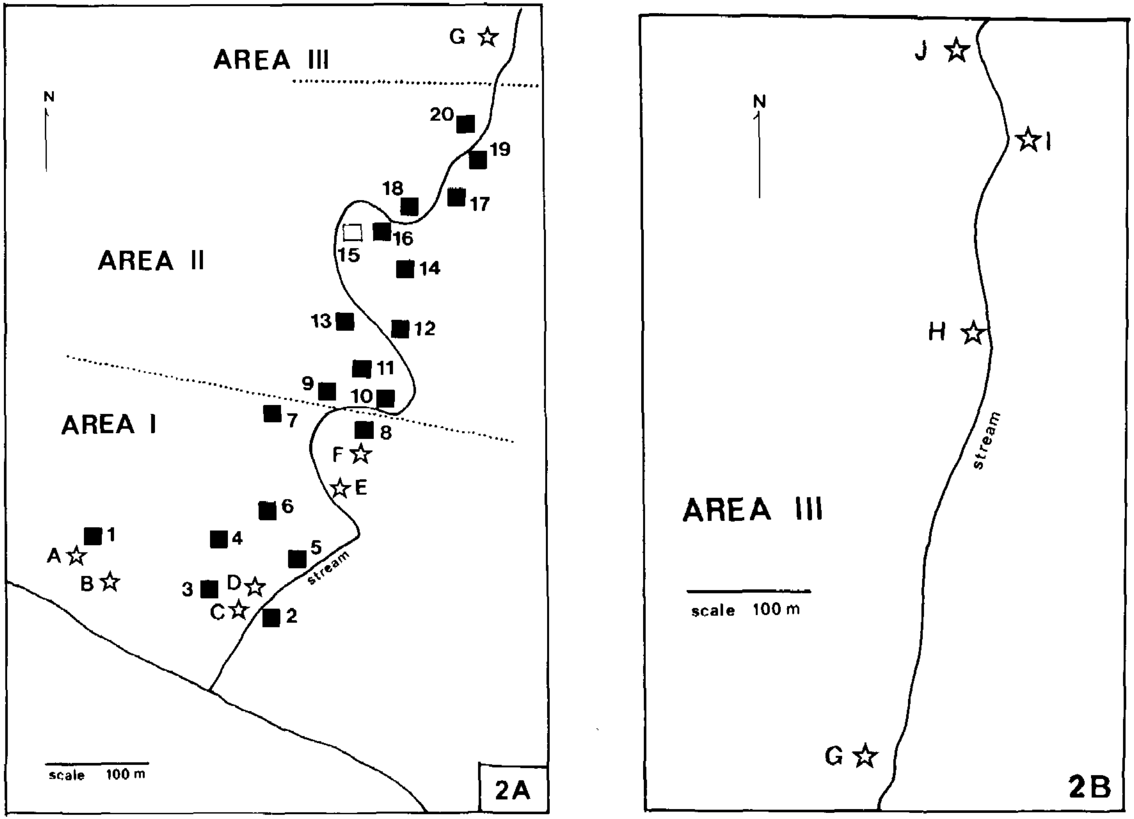


FIGURE 2 — Location of natural nest sites and of boxes in the study area. Map B is the northern continuation of Map A. ☆ = natural site. ■ = box. Box 15 is shown by an open square as it was destroyed in 1985

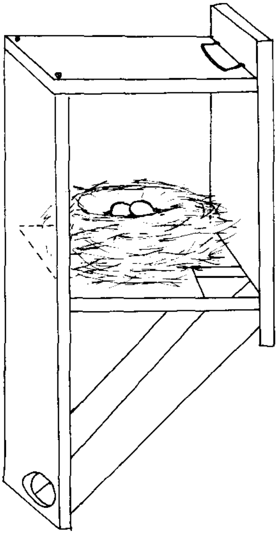


FIGURE 3 — Stitchbird nest box, cutaway view. The nest "cavity" measures 15 cm × 20 cm × 20 cm (width × length × height). The tunnel is 24 cm long (approximately)

chloris), Kakariki (*Cyanoramphus* spp.), and New Zealand Kingfisher (*Halcyon sancta*). The boxes were built of 2.5 cm tanalised pine. The tops were hinged at the back and fastened with screws so that I could easily remove them to see inside the box.

Eight boxes were put up in Area I and 12 in Area II (Figure 2). The boxes were erected in August 1984, before the breeding season, which begins some time from September to November. Boxes were placed 2-5 m up in various species of tree, the height being limited by the ladder. Aspect was not taken into account, except that no opening faced downstream into the prevailing breeze.

Boxes in Area I were there to increase the density of nest sites available in a known breeding habitat. The boxes were erected in Area II to test whether Stitchbirds had not been nesting in this area because of the lack of natural nest sites. No boxes were erected in Area III, as a control to monitor any natural increases in breeding density. Since the habitat varied between areas, density changes may have been related to habitat type. Therefore the control area was not ideal.

To test the hypothesis that availability of nest sites was limiting the potential for polygamy in male Stitchbirds, four boxes (numbers 1,2,6 and 8) were placed within 5 m of known natural nest sites. Six boxes (numbers 12,13,15,16,17, and 18) were within 10 m of another box.

During the breeding season each box and natural site was watched for at least one hour per trip. After the breeding season, boxes were opened and checked for nests. From the size of the nests and eggshell remains the nests could be identified as Stitchbird nests.

Monitoring effort varied from year to year. Observation was nearly daily in the summers of 1983-1984 and 1986-1987, several visits to the island were made in 1982-1983 and 1984-1985, and only two visits, one during and one after the breeding season, were made in 1985-1986.

RESULTS

No nest boxes were used by Stitchbirds during the first breeding season that the boxes were available (summer 1984-1985). Singing by male Stitchbirds was conspicuous in the valley as the boxes were being set up, and so the Stitchbirds may have already chosen nest sites. Therefore in Table 1, the 1984-1985 summer was considered along with 1982 and 1983 as being a summer before the addition of boxes.

Two boxes (numbers 8 and 9) were used as nest sites in 1985-1986, and two other boxes (numbers 7 and 13) were used in 1986-1987 (Table 1). There was no increase in the number of nests used in any one year within the entire nest box area (both Area I and Area II). The number of nests used per year did not exceed past records in Area I, but Stitchbirds nested for the first time in Area II because of their using the boxes. There was a decline in active nests in Area III.

If the experimental areas (Areas I and II) are considered together, the average number of nest sites used was 2 per year before the boxes were added and 3 per year afterwards. For the control (Area III), the average was 2.3 nests per year before boxes, and 0.5 nests afterwards. A chi-square test indicates that the change in the ratio between the two areas was not significant ($x^2 = 1.91$, df = 1, p = 0.10) (Parker 1979).

I may have missed nests in Area III in 1985-1986 because of my limited observation effort. During my only breeding season visit, I did see a pair of Stitchbirds at site J but could not confirm actual nesting.

I did not observe any male Stitchbirds defending more than one nest or more than one female. Nest site F and Box 8, less than 1 m apart on the same tree, were both used but not in the same year.

There appeared to be a trend for the birds to select the higher boxes. Whereas the mean height for all boxes was 3.2 m (SE = 0.19, range = 1-5 m, n = 19), the mean height of the four boxes used by Stitchbirds was 3.5 m (SE = 0.29, range = 3-4). The mean height for natural sites was 5.0 m (SE = 0.92, range = 1-10 m, n = 10). These differences in height were tested by the Mann-Whitney U test (Runyon 1977), but there were no significant differences between the average heights (Table 2). No other cavity-nesting bird species were found nesting in the artificial sites, although cave wetas (*Gymnoplectron* sp.) and geckos (*Hoplodactylus pacificus*) used them extensively.

The nests in boxes 7 and 8 failed at an early stage. No activity by adult Stitchbirds was detected at these sites during the breeding season. On examining the boxes during the following autumn, I found three dead nestlings in each box and one well-developed dead nestling in box 9.

The boxes remained in good condition, except for box 15, which was knocked down by a falling branch in the winter of 1985.

TABLE 1 — Nest sites used by Stitchbirds in the Tirikakawa Valley, 1982-1987. 'Site' refers to natural sites.

	Season used				
	1982-1983	1983-1984	1984-1985	1985-1986	1986-1987
Boxes	NA	NA	NA	up	up
1) Experiment					
Area 1 (3 ha)					
Site A	.	x	.	.	.
Site B	.	.	.	x	x
Site C	x	.	.	.	.
Site D	.	x	.	.	.
Boxes 1-6	.	.	.	.	.
Site E	x	x	.	.	.
Box 7	.	.	.	.	x
Site F	.	.	x	.	.
Box 8	.	.	.	x	.
Area II (2.8 ha)					
Box 9	.	.	.	x	.
Boxes 10-12	.	.	.	.	.
Box 13	.	.	.	.	x
Box 14-20	.	.	.	.	.
Total sites used in Areas I and II	2	3	1	3	3
2) Control					
Area III (5.5 ha)					
Site G	.	x	x	.	.
Site H	.	x	x	.	.
Site I	x	.	.	.	.
Site J	.	x	x	.	x
Total sites used in Area III	1	3	3	0	1

The nests in boxes 7 and 8 failed at an early stage. No activity by adult Stitchbirds was detected at these sites during the breeding season. On examining the boxes during the following autumn, I found three dead nestlings in each box and one well-developed dead nestling in box 9.

The boxes remained in good condition, except for box 15, which was knocked down by a falling branch in the winter of 1985.

TABLE 2 — Mann-Whitney 'U' test for differences in means among natural nest sites, boxes and boxes used

Comparison	U	U'
Nest sites and boxes	63	127
Nest sites and boxes used	15	25
Boxes and boxes used	29	47

At p = 0.10, these values were not significant (Table H, Runyon 1977).

DISCUSSION

Stitchbirds use of nest boxes: This experiment showed that nest boxes have excellent potenial as a management tool for Sticthbirds. The birds used the boxes despite the abundance of natural sites. In a similar study, Eastern Bluebirds *(Sialia sialis)* actually preferred artifical sites over natural sites (Pinkowski) 1979).

The nest boxes also served to provide exclusive sites for Stitchbirds alone. The nest boxes could prevent aggressive introduced cavity nesters such as the Indian Myna *(Acridotherses tristis)* or the European Starling *(Sturnus vulgaris)* from taking over Stitchbird nesting habitat.

The failure of two nests in boxes may have been due to overheating or inadequate ventilation. Consequently, at the end of the 1986-87 breeding season, I drilled holes into the sides of the boxes to increase the circulation of air. The boxes will be monitored over the next few breeding seasons to see whether nest sucess increases.

Sire limitation and breeding density: The number of natural sites that were discovered may partly depend on the amount of effort spent looking for these nests. I made only one week-long visit during the breeding season of 1985-86 and found only one natural site. My failure to notice Stitchbird activity around unsucessful nests in nest boxes indicates that incomplete nesting attempts in natural sites may go completely undetected.

Even so, it would appear that nest boxes did not cause a large increase in the number of Stitchbirds nesting in the experimental area. The appearance of Stitchbird nests in the previously unused Area II indicates that sites were a limited resource in this area.

As breeding density did not increase in Area I, and as the number of nests in Area II was well below the number of boxes available, it would appear that other factors are limiting the numbers of pairs nesting there. Food may be the limiting resource (Rasch 1985b). Northern Hemishere studies on nest boxes have used insectivorous birsd as their experimental subjects (e.g. Enemar & Sjostrand 1972, Slagsvold 1975, Pinkowski 1979, van Balen *et al.* 1982, Brush 1983, Nilsson 1984). Perhaps insects are more consistently abundant the the nectar and fruit which Stitchbirds feed on.

Why the use of natural sites decreased in Area II is unknown. The more diverse tawa forest in Area III would appear to be better habtit than the transitional kanuka/tawa forest of Area II. As the boxes used by Stitchbirds in Area II were not those nearest to Area III, birds were more likely moving from Area I and not from Area III. The use of Area II and the drop in use of Area III may therefore be unrelated events.

Therefore nest sites availability does not always limit the breeding density of Stitchbirds. Brush (1983) reported similar variability in the effects of adding nest boxes in his study of cavity nesters along the Colorado River. He suggested that the dramatic increases of cavity nesters in other studies (e.g. Hogstadt 1975) was a result of using heavily modified forests as study sites.

Polygamy: It is also unlikely that the lack of nest sites was a factor in preventing polygamy in Stitchbirds. From the large number of unmated males present, the sex ratio seemed to be biased towards males. Female aggression towards other female Stitchbirds (Rasch 1985a) may prevent males from taking additional mates (Wittenberger & Tilson 1980). Polygamy may occur only in populations where the sex ratio is heavily biased towards females.

A transfer population of Stitchbirds illustrates this hypothesis in reverse. Only one female and 17 male Stitchbirds were left on Cuvier Island in November 1986 after transfers from Little Barrier in 1982 and 1985. Because of the number of males at the only nest site, it was impossible for the territory owner (banded for recognition) to keep the other males away from his nest and female (pers. obs.). It appeared that other males were attempting to copulate with the female. Multiple fathers of a single clutch are not unknown in normally monogamous passerines (Ford 1983) and may have occurred at this Stitchbird nest.

Although the sample sizes in this experiment were too small to support definte conclusions about theories on cavity-nesting, I did show that Stitchbirds will use artificial nest sites. With an improvement in design, nest boxes could be useful in promoting the induction of Stitchbirds to rehabilitated sites (such as Tiritiri Matangi Island) where the re-established forest is too young to provide natural nest sites.

ACKNOWLEDGEMENTS

This study began as part of an MSc thesis at Auckland University. I thank John Craig and Goerge Angehre for their help. For help with the boxes I thank Mark Vette, Rod Hay, Tim Lovegrove, Craig Hodsell, Alec Dobbins, and the 1984 Stitchbird transfer team. George Angehr and Terry Greene provided nest site imformation. Drafts of this paper were improved by the comments of Suzanne Clegg, John Craig, Fiona Eadie, Rod Hay, Dave Hunt, and Dick Veitch. Financial support was given by the Wildlife Service, the Department of Lands and Survey, the Royal Forest and Bird Protection Society, and the Frank Chapman Fund of the American Museum of Natural History. Access to Little Barrier was granted by the Hauraki Gulf Martime Park Board.

LITERATURE CITED

ALCOCK, J. 1984. Animal Behaviour, An Evolutionary Approach. 3rd edition. Massachusetts: Sinauer Assoc. Inc.

VAN BALEN, J. H.; BOOY, C. J. H.; VAN FRANEKER, J. A.; OSIEK, E. R. 1982. Studies on hole-nesting birds in natural nest sites. 1. Availability and occupation of natural nest sites. Ardea 70: 1-24.

BRUSH, T. 1983. Cavity use by secondry cavity-nesting birds and response to manipulations. Condor 85: 461-466.

EMLEN, S. T.; ORING, L. W. 1977. Ecology, sexual selection, and the evolution of mating systems. Science 197: 215-223.

ENEMAR, A.; SJOSTRAND, B. 1972. Effects of the introduction of Pied Flycatchers *Ficedula hypoleuca* on the composition of a passerine bird community. Ornis Scand. 3: 79-89.

FORD, N. L. 1983. Variation in mate fidelity in monogamous birds. *In* Current Ornithology, vol 1. Johnston, R. F., ed. New York: Plenum Press.

VON HAARTMAN, L. 1957. adaption in hole-nesting birds. Evolution 11: 339-347.

HERLUGSON, C. J. 1983. Nest site selection in Mountain Bluebirds. Condor 83: 252-255

HOGSTADT, O. 1975. Quantitive relations between hole-nesting and open-nesting species within a passerine breeding community. Norw. J. Zool. 23: 261-267.

KERBS, J. R.; DAVIES, N. B. 1981. An Introduction to Behavioural Ecology. Oxford: Blackwell Scientific Publications.

LACK, D. 1968. Ecological Adaptations for Breeding in Birds. London: Methuen.

NICE M. M. 1957. Nesting success in altricial birds. Auk 74: 305-321.

NILSSON, S. G. 1984. The evolution of nest-site selection among hole-nesting birds: the importance of nest predation and competition. Ornis Scand. 15: 167-175.

PARKER, R. E. 1979. Introductory Statistics for Biology. Studies in Biology No. 43. 2nd edition. London: Edward Arnold.

PINKOWSKI, B. C. 1979. Nest site selection in Eastern Bluebirds. Condor 81: 435-436.

RASCH, G. 1985b. The behavioural ecology and management of the Stitchbird. Unpubl. MSc thesis. University of Auckland.

RASCH, G. 1985b. The ecology of cavity nesting inthe Stitchbird (*Notiomystis cincta*). NZ J. Zool. 12: 637-642.
RUNYON, R. P. 1977. Nonparametric Statistics: A Contemporary Approach. Massachusetts: Addison and Wesley Publ. Co.
SLAGSVOLD, T. 1975. Competition between the Great Tit *Parus major* and the Pied Flycatcher *Ficedula hypoleuca* in the breeding season. Ornis Scand. 6: 179-190.
WITTENBERGER, J. F.; TILSON, R. L. 1980. The evolution of monogamy: hypothesis and evidence. Ann. Rev. Ecol. Sys. 11: 197-232.

GRETCHEN RASCH, *Lake Okareka, Rotorua*

SHORT NOTE

Mummified moa remains from Mt Owen, northwest Nelson

Discovery: During the Christmas period 1986-87, members of the New Zealand Speleological Society were in northwest Nelson at Mt Owen, a marble mountain with well-developed karst features and many caves. On 7 January 1987, several cavers were excavating a route through a debris choke to link two caves, when they saw some moa remains. As muscle and skin tissues still adhered to the bones, Paul Wopereis spoke to me by radio.

This discovery was greeted with tremendous excitement at the National Museum of New Zealand because mummified remains of moas are very rare (10 previous records). On 8 January, J. A. Bartle, M. Strange and I went to the expedition's camp at Lake Bulmer on Mt Owen to examine the discovery for the National Museum.

The site: The mummified remains were found in Blowhole Cave where it connects with Whalesmouth Cavern, grid reference S26 c 934 947. The site is 1160 m a.s.l., which is about 100 m below the upper limit of forest and about 716 m below the summit of Mt Owen (1876 m).

The bones and tissues were disarticulated, scattered vertically through 2 m of rockfall debris. The tissue was attached only to those bones which were within the area swept by a strong draught of air between the two caves. Bones not in the draught had no tissue and were damp, and so the tissue had been preserved mainly by the drying effect of this air flow.

Skeletal remains: From characters outlined by Worthy (1988) the remains were identified as one *Megalapteryx didinus* (Owen). As the bones were fairly disassociated, several elements are lost, but those present include: right side of mandible; vertebrae including the atlas, axis, 10 cervical and 2 thoracic vertebrae; 5 thoracic ribs, 5 sternal ribs; left and right (LR) coracoid-scapulae; pelvis; LR tibiotarsi; LR fibulae; LR tarsometatarsi; complete complement of left phalanges, 9 R phalanges. A left femur found 10 m away from the other remains is regarded as belonging to this bird. Many tracheal rings were also present. The remains are now in the National Museum of New Zealand (catalogue number S 23808).

Tissue remains: Best preserved was the tarsometatarus and associated toes of the left foot (Fig. 1, 2). The pads and dorsal scales are present, although the horny claws of the terminal phalanges are missing. Much muscle tissue has been preserved on this tarsometatarus, but a large piece, showing scutes and feather pits, had become separated from the bone at the tibiotarsal articulation. The phalanges of the right foot are free and bare of tissue, but much tissue remains on the proximal tarsometatarsus. The left tibiotarsus (sacrificed for 14C dating) and fibula have no preserved tissue adhering to them, but the equivalent right elements do. The pelvis has a large piece of skin on its dorsal surface, beneath which are muscle and connective tissues, particularly in the iliac region. Similar tissues are retained on some ribs and vertebrae. In addition many loose strips of muscle and two large muscle blocks were found separated from bones. A few fragmentary feathers were found with the loose tissue. Some of this tissue is being studied by G. Chambers of the Biochemistry Department, Victoria University of Wellington.

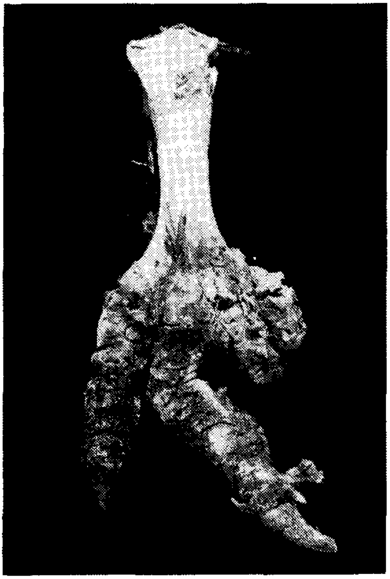


FIGURE 1 — Dorsal view of the left foot of Mt Owen specimen of *M. didinus*

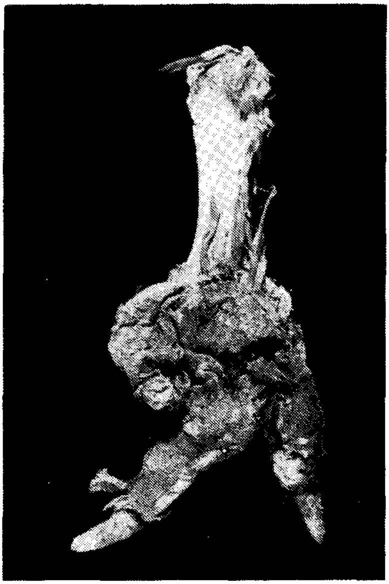


FIGURE 2 — Ventral view of left foot of Mt Owen specimen of *M. didinus*

(Photos: National Museum)

Age of remains: The left tibiotarsus, fossil record number M28/f250, was radiocarbon dated, using bone collagen, by the Institute of Nuclear Sciences (DSIR). The age estimate, based on the Libby half-life (T½ = 5568 yr) was 3350 ± 70 yr BP. A sample of dried flesh was also dated, giving an age estimate, based on Libby (T½ = 5568 yr), of 2120 ± 310 yr BP. I consider the age based on bone collagen to be more reliable because bacterial contamination of the flesh may easily have introduced, even at low levels, modern carbon to the sample.

Size of the bird: Measurements of the long bones of the Mt Owen specimen are femur 231 mm, tibiotarsus 352 mm, tarsometatarsus 158 mm. The length ranges for bones of this species given by Worthy (1988) for specimens from Honeycomb Hill Cave, northwest Nelson, are femur 220-315 mm, tibiotarsus

340-490 mm, tarsometatarsus 150-220 mm. The Mt Owen specimen therefore was a small individual of the species.

Discussion: Although some 10 records of mummified moa tissue are known (Atholl Anderson, pers. comm. 1987), all are from the southern central region of the South Island. Only three records of *M. didinus* with preserved tissue were known previously (Oliver 1949): The type of the species, which is held in the British Museum (A16) and was collected from Queenstown in 1876, is a complete skeleton with much tissue; a leg, consisting of articulated bones, muscle, skin and feathers, found in the Old Man Range, is now in the Otago Museum (C.68.2); and a skeleton with well-preserved tissue on the head and neck region, collected from the Cromwell area, is now in the National Museum of New Zealand (NMNZ S400).

The excellent preservation of these three specimens led Oliver (1949) to say that the remains were "well under a thousand years old", resulting in the theory that this was the last species to become extinct (Oliver 1949: 151). However, a specimen of *Anomalopteryx didiformis* from Echo Valley near Lake Te Anau, now in the Southland Museum and Art Gallery, has preserved tissue (Forrest 1987). So have *Emeus* remains from Earnscleugh Cave (Coughtrey 1875), *Dinornis* remains from Knobby Range (Hutton 1875) and Tiger Hill (Hector 1871), and some bones of *Pachyornis elephantopus* from "Otago" (A. Anderson, pers. comm. 1987). Thus specimens of several species have preserved tissue. The common factor is not the species but the location: all are from caves in the dry central regions of Otago and Southland. Whereas these have been preserved by the dry atmosphere, the Mt Owen specimen was preserved by the drying action of air movement.

The Mt Owen specimen is the first moa with preserved tissue that has been dated. An age of over 3300 years for this specimen clearly shows that similar remains need not be young.

ACKNOWLEDGMENTS

The scientific acumen of the cavers who discovered these remains and brought them to the attention of the National Museum is greatly appreciated. Permission to retrieve the remains was given by New Zealand Forest Service, without whose co-operation this most significant find could not have been described or studied. The co-operation of P. Wopereis and C. Smith in examining and retrieving the specimens was essential to the outcome of this investigation. M. Strange took the photographs and, together with J. A. Bartle, excavated most of the recovered material.

LITERATURE CITED

COUGHTREY, M. 1875. Anatomy of moa remains found at Earnscleugh Cave. Trans. NZ Inst. 9: 141-144.
FORREST, R. M. 1987. A partially mummified skeleton of *Anomalopteryx didiformis* from Southland. J. Royal Soc. 17: 399-408.
HECTOR, J. 1871. On recent moa remains in New Zealand. Trans NZ Inst. 4:110-120.
HUTTON, F. W. 1875. Moa remains from Knobby Range. Trans NZ Inst. 7: 266-268.
OLIVER, W.R.B. 1949. The moas of New Zealand and Australia. Dom. Mus. Bull. 15.
WORTHY, T. H. 1988. A re-examination of the moa genus *Megalapteryx* in New Zealand. Notornis 35: 99-108.

T. H. WORTHY, *National Museum, Wellington*

SUBSPECIATION IN THE RED-TAILED TROPICBIRD

By MICHAEL K. TARBURTON

ABSTRACT

This study shows that the Red-tailed Tropicbird (*Phaethon rubricauda*) has a gradual clinal increase in the intensity of the rose-pink suffusion, egg size, culmen length and wing length in breeding populations between Kure Atoll in the northern Pacific and the Kermadec Islands in the southern Pacific. The illusion that birds from this cline comprise three subspecies has long been accepted because the large range of latitude that each subspecies had been arbitrarily given resulted in significant differences in mean measurements. However, as neither the northern *rothschildi* nor the southern *roseotincta* are clearly separable from *melanorhynchos* in the centre of the cline, they must all be one subspecies. Because the mean measurements of the nominate "subspecies" are not significantly different from those of birds from similar latitudes in the Pacific cline, or from *westralis* in the eastern Indian Ocean, there is no valid reason for distinguishing any subspecies in the Red-tailed Tropicbird.

INTRODUCTION

Mayr (1982) has suggested that many of the subspecies described in the first half of this century "did not differ in the slightest and that the recognition of minutely differing populations served, in most cases, no good purpose." Gill (1982) has also suggested that further study of many classical subspecies will lead to their elimination.

Here I examine geographical variation in the Red-tailed Tropicbird (*Phaethon rubricauda*) throughout its Indo-Pacific breeding range. My purpose is to assess the validity of the five subspecific groupings ascribed to the species by Peters (1931) and still in common use: *P. r. rubricauda* in the western Indian Ocean, *P. r. westralis* in the eastern Indian Ocean, *P. r. rothschildi* in the northern Pacific Ocean, *P. r. melanorhynchos* in the central Pacific, and *P. r. roseotincta* in the southern Pacific.

METHODS

The three diagnostic characters originally used to separate the five subspecies were wing length, culmen length and pinkness of plumage. I obtained measurements of these characters mainly from skins in the museums listed in the acknowledgments. Some data were available from the literature (Gibson-Hill 1950, Hindwood *et al.* 1963, Fleet 1974, Diamond 1975). Live birds were measured on Kure Atoll, Sugarloaf Rock, Aldabra Island and Norfolk Island.

I measured the wing held flattened on to a ruler and the culmen from the feather line to the tip. To compare the intensity of pink suffusion in the white feathers I used the scale that Fleet (1974) used to measure seasonal variations of this character on Kure Atoll, Hawaii. The categories are nil, slight, moderate, strong and intense.

NOTORNIS 36: 39-49 (1989)

These data were compiled so as to compare traditional subspecific and island groupings. By also comparing these data and those for egg size with latitude, I discovered correlations not previously observed.

TABLE 1 — Average wing, culmen and egg measurements from breeding populations

Island	Latitude	Wing Length	S.E.	n	Culmen Length	S.E.	n	Egg Length	S.E.	Egg Width	S.E.	n
Kure	28N	319.2	1.0	71	62.4	0.3	70	64.2	0.2	45.1	0.1	300
Midway	28N	313.8	3.3	12	61.7	0.6	13	64.6	0.6	44.9	0.2	22
Bonin	27N	318.0	1.8	8	58.7	0.5	8	63.1	0.9	45.0	0.5	5
Laysan	26N	314.6	1.4	53	61.2	0.3	58	63.7	0.5	44.6	0.3	33
Lisianski	26N	-	-	-	64.5	-	2	-	-	-	-	-
Necker	25N	319.5	6.5	2	61.8	0.8	2	-	-	-	-	-
Marcus	23N	318.3	1.9	3	61.0	1.0	3	-	-	-	-	-
Kruzenstern	23N	313.5	6.5	2	56.5	0.3	2	-	-	-	-	-
Kauai	22N	322.0	3.5	4	63.7	2.6	3	-	-	-	-	-
Nihoa	22N	327.0	0.0	2	63.7	1.0	2	-	-	-	-	-
Wake	20N	321.6	3.8	5	59.4	1.4	9	67.5	-	45.1	-	1
Pagan	18N	314.0	-	1	58.0	-	1	63.6	0.7	44.2	0.5	8
Nihau	18N	319.5	1.6	2	62.0	4.0	2	-	-	-	-	-
Johnston	17N	316.5	1.7	17	61.5	1.0	12	-	-	-	-	-
Marquesas	10N	331.3	2.1	10	63.6	0.5	10	-	-	-	-	-
Clipperton	10N	320.0	-	1	60.9	-	1	-	-	-	-	-
Marshall	9N	319.0	1.5	3	59.9	1.3	4	-	-	-	-	-
Palmyra	7N	328.5	-	2	61.8	-	2	-	-	-	-	-
Atjah	6N	320.0	-	1	66.0	-	1	-	-	-	-	-
Christmas(Pac)	2N	335.0	2.9	13	64.2	1.1	11	67.4	0.8	46.0	0.4	13
Howland	1N	335.8	2.9	10	63.8	0.7	10	-	-	-	-	-
Jarvis	0	328.8	1.9	16	62.4	0.7	15	-	-	-	-	-
Enderbury	3S	340.0	3.6	3	62.9	0.8	5	63.5	0.7	45.5	0.6	5
Canton	3S	335.3	6.1	4	62.5	1.5	4	65.4	-	42.9	-	1
McKean	4S	-	-	-	60.5	-	1	-	-	-	-	-
Seychelle	4S	342.0	5.7	3	67.3	1.2	3	-	-	-	-	-
Hull	5S	337.6	1.3	31	62.5	2.5	31	67.8	1.0	46.3	0.8	4
Starbuck	5S	-	-	-	60.5	-	1	-	-	-	-	-
Goenoeng Api	7S	321.3	7.0	3	58.3	1.8	3	-	-	-	-	-
Aldabra	9S	335.8	1.4	27	64.0	0.5	29	65.1	-	46.4	-	8
Raine	11S	329.9	4.6	11	65.0	1.2	11	69.0	-	48.5	-	2
Christmas(Ind)	11S	328.2	2.7	21	64.8	0.4	21	69.0	-	48.8	-	5
Cocos-Keeling	12S	333.3	3.5	6	63.5	0.8	21	63.5	-	44.5	-	-
Samoa(Rose)	12S	338.0	1.0	2	62.5	2.5	2	-	-	-	-	-
Suvarov/Takutea	13S	341.1	1.1	49	64.8	1.2	49	68.1	0.4	46.1	0.4	8
Tuamotu	17S	339.0	2.1	31	66.4	1.2	31	67.1	-	46.9	-	34
Madagascar	18S	337.5	3.5	2	65.5	0.5	2	-	-	-	-	-
Mauritius	20S	330.3	2.7	10	66.0	0.8	13	64.9	1.2	46.9	0.7	7
Rodriquez	20S	327.0	-	1	67.0	-	1	-	-	-	-	-
Tonga	20S	338.4	3.1	11	64.8	1.2	11	-	-	-	-	-
Brampton	20S	-	-	-	67.5	-	2	-	-	-	-	-
Gambier	21S	338.0	-	1	66.0	-	1	-	-	-	-	-
New Caledonia	22S	323.0	-	1	65.0	-	2	-	-	-	-	-
Wreck	23S	331.0	1.0	2	67.5	1.5	2	-	-	-	-	-
Oeno	24S	345.0	1.6	8	67.6	0.9	8	67.0	0.8	46.6	0.3	10
Henderson	24S	342.4	4.4	7	64.3	0.9	7	-	-	-	-	-
Ducie	25S	345.8	3.2	5	67.3	1.1	6	66.6	1.1	46.6	0.4	14
Austral	25S	343.0	-	1	65.0	-	1	-	-	-	-	-
Rapa	27S	341.0	2.2	8	66.7	0.6	8	-	-	-	-	-
Easter	27S	330.0	-	1	-	-	-	-	-	-	-	-
Abrolhos	28S	335.6	2.5	8	66.5	0.8	8	66.0	-	48.0	-	6
Norfolk/Phillip	29S	348.9	1.8	41	66.4	0.4	41	67.7	3.9	47.7	0.3	22
Kermadec	31S	343.9	1.2	58	66.2	0.3	55	67.2	0.9	47.4	0.7	6
Lord Howe	32S	341.3	1.5	45	67.6	1.9	46	65.4	1.8	47.6	1.0	3
Broughton	33S	325.0	-	1	63.0	-	1	-	-	-	-	-
Sugarloaf	34S	342.2	2.7	14	64.8	0.4	30	65.6	1.1	46.8	0.5	7
TOTAL				654			698					524

RESULTS

Table 1 gives average bird and egg measurements for every island from which I could get data. Although the sample sizes vary, the larger samples are evenly spread over the latitudes.

As the previously accepted subspecies were based on certain groupings of the island populations, I have examined the data under these divisions.

P. r. westralis

There is no significant difference between the mean exposed culmen lengths ($t = 0.545$, $P > 0.1$, $df = 104$) or mean wing lengths ($t = 2.082$, $P > 0.1$, $df = 93$) of *rubricauda* and *westralis*. *P. r. rubricauda* has a wing of 334.84 ± 1.23 mm ($\bar{x} \pm$ SE, $n = 43$) and an exposed culmen of 64.86 ± 0.39 mm ($n = 48$); whereas *westralis* has a wing of 333.33 ± 1.68 mm ($n = 52$) and a culmen of 64.25 ± 0.38 mm ($n = 68$).

Skins of *rubricauda* show no pink suffusion. Diamond (pers. comm.) verified this in the field, although he found one or two birds with a slight suffusion of pink. In the eastern Indian Ocean (Sugarloaf Rock) I found nesting birds of all intensity scalings, although the average was moderate (Tarburton 1977).

P. r. rothschildi

Specimens from the northern Pacific are smaller and less pink than those from the southern Pacific. For example, the average exposed culmen and wing lengths of 71 birds (Fleet, pers. comm.) from Kure Atoll (the northernmost Pacific colony) are significantly smaller (Table 2) than those of 41 birds from Norfolk Island (one of the southernmost Pacific colonies). The intensity of the pink tinge (Table 3) is also significantly different ($P < 0.01$) between the two islands.

TABLE 2 — Statistical differences in measurements for birds from populations at the extremes of the cline in the Pacific Ocean

	Norfolk Population (Average ± SE)	Kure Population (Average ± SE)	t	P
Wing	348.9 ± 1.8	319.2 ± 1.0	14.62	<0.001
Culmen	66.4 ± 0.4	62.4 ± 0.3	14.92	<0.001

TABLE 3 — Statistical differences in the intensity of the pink suffusion in live birds from populations at the extremes of the cline in the Pacific Ocean

		Intense	Strong	Moderate	Slight	Nil	χ^2	P
Norfolk	(O)	9	8	11	4	0		
Kure	(E)	3	7	28	4	0	22.46	<0.01

TABLE 4 — Measurements of diagnostic characters for currently accepted subspecies

	Character	$\bar{x}$	SE	n
	Wing			
rothschildi		317.30	0.67	180
westralis		334.55	1.70	49
rubricauda		334.84	1.23	43
melanorhynchos		337.20	0.69	210
roseotincta		342.30	0.99	163
	Exposed Culmen			
rothschildi		61.58	0.20	185
westralis		64.25	0.38	68
rubricauda		64.86	0.39	48
melanorhynchos		64.43	0.20	212
roseotincta		66.40	0.24	164
	Pinkness			
rothschildi		2.28	0.11	96
westralis		3.17	0.08	42
rubricauda		1.06	0.04	31
melanorhynchos		1.02	0.02	139
roseotincta		3.16	0.19	55

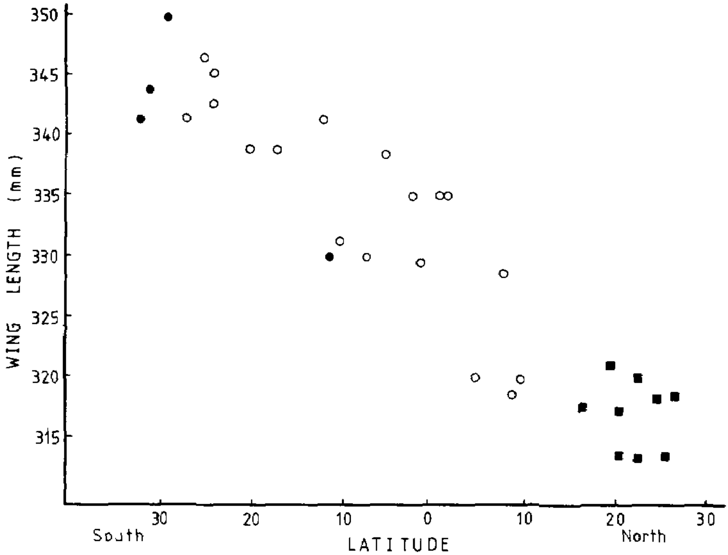


FIGURE 1 — The clinal relationship between wing length and latitude in Pacific Ocean populations. Solid circles represent samples from those populations originally designated as *P. r. roseotincta*. Hollow circles represent *P. r. melanorhynchos*, and solid squares represent *P. r. rothschildi*

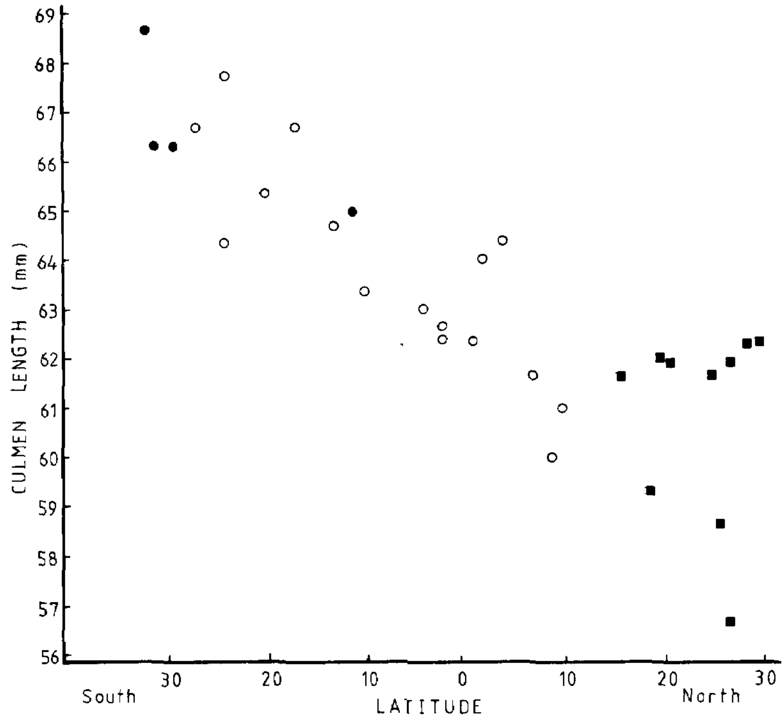


FIGURE 2 — The clinal relationship between exposed culmen length and latitude in Pacific Ocean populations. Solid circles represent samples from those populations originally designated as *P. r. roseotincta*. Hollow circles represent *P. R. melanorhynchos*, and solid squares represent *P. r. rothschildi*

The average for the total sample of *rothschildi* (Table 4) shows that they have a smaller wing ($t = 20.7$, $P < 0.001$, $df = 388$) and exposed culmen ($t = 9.6$, $P < 0.001$, $df = 395$) and have significantly more pink ($t = 11.3$, $P < 0.001$, $df = 234$) than *melanorhynchos*. However, both culmen and wing measurements are clinal (Figures 1 and 2), and so these differences are not sharp distinctions.

P. r. roseotincta

This subspecies has a larger wing ($t = 4.2$, $P < 0.001$, $df = 371$) and exposed culmen ($t = 6.1$, $P < 0.001$, $df = 374$) and is significantly more pink ($t = 58.6$, $P < 0.001$, $df = 193$) than *melanorhynchos*.

P. r. melanorhynchos

Although the average lengths of culmen and wing for the total sample of *melanorhynchos* are significantly different from those of *rothschildi* and *roseotincta*, Figures 1 and 2 show that the averages for the island populations within this "subspecies" form a gradual cline between those at the extreme latitudes of the Pacific. In addition, *melanorhynchos* is not significantly different from the nominate subspecies *rubricauda* in wing ($t = 1.2$, $P > 0.1$, $df = 251$), exposed culmen ($t = 1.0$, $P > 0.1$, $df = 258$), or intensity of pinkness ($t = 0.9$, $P > 0.1$, $df = 168$). Neither is *melanorhynchos* significantly different from *westralis* in wing ($t = 1.4$, $P > 0.05$, $df = 255$) or exposed culmen ($t = 0.42$, $P > 0.25$, $df = 278$).

Average egg size for each island also varied with latitude. Significant correlations were found between latitude and egg length ($r = 0.49$, $P < 0.01$, $n = 25$) and latitude and egg width ($r = 0.74$, $P < 0.01$, $n = 25$). These correlations are graphed in Figures 3 and 4.

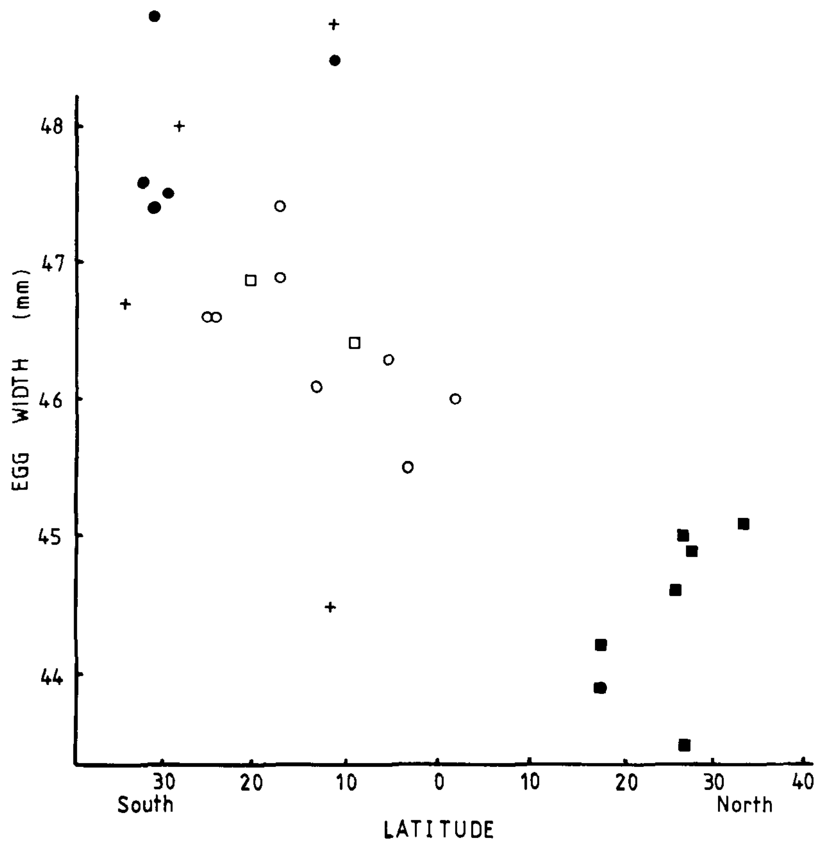


FIGURE 3 — The clinal relationship between egg width and latitude. Solid circles represent samples from those populations originally designated as *P. r. roseotincta*. Addition signs represent *P. r. westralis*, hollow circles represent *P. r. melanorhynchos*, hollow squares represent *P. r. rubricauda*, and solid squares represent *P. r. rothschildi*

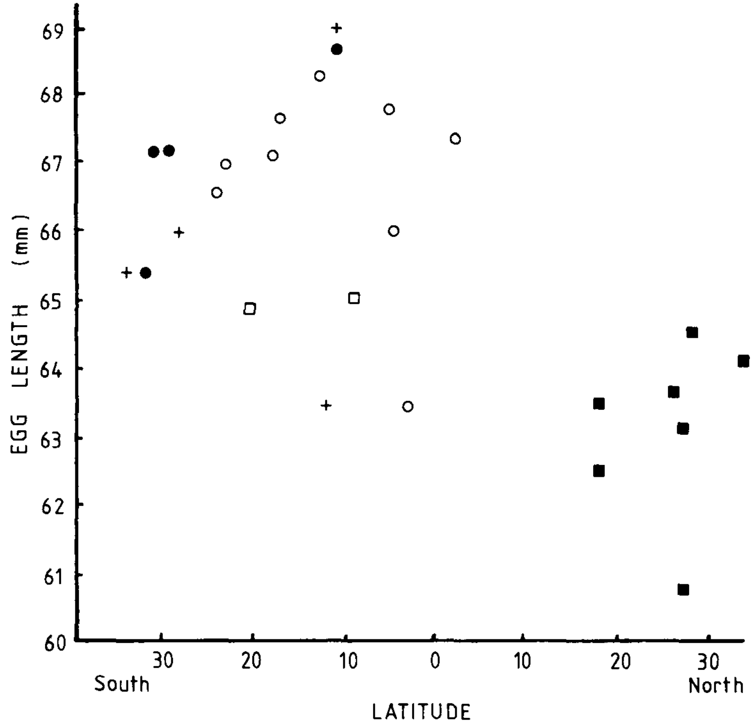


FIGURE 4 — The clinal relationship between egg length and latitude. Solid circles represent samples for those populations originally designated as *P. r. roseotincta*. Addition signs represent *P.r. westralis*, hollow circles represent *P. r. melanorhynchos*, hollow squares represent *P. r. rubricauda*, and solid squares represent *P. r. rothschildi*

DISCUSSION

P. r. westralis

The type specimen of *rubicauda* was described by Boddaert in 1783 and, even though it and several other specimens were taken from Mauritius, the subspecific range was given as the western Indian Ocean (Peters 1931). Rothschild (1900) was the first to record that birds from the eastern Indian Ocean (Christmas Island) were different from those nesting in the Western Indian Ocean. However, he acknowledged that a larger series was needed before the impression could be confirmed. Later, the sample from the eastern Indian Ocean was enlarged by·the addition of some specimens from the Abrolhos Islands (Mathews 1914-15: 305, although on p.302 Mathews gave their origin as Rottnest Island). They were together described (Mathews

1912, 1914-15) as the subspecies *westralis.* Mathews said those specimens ascribed to the new subspecies had rosier coloration, a rather smaller bill, and a longer wing than the type. The measurements he gave supported the difference in bill size because the two ranges did not overlap. However, the wing lengths he gave (*rubricauda* 320-336, *westralis* 320-341) overlapped greatly.

Gibson-Hill (1950), in assigning two birds from the Cocos-Keeling Islands to *westralis,* continued the subspecific distinction. It is clear, from comparing the data in Mathews (1912, 1914-15) and Gibson-Hill (1950) with the skins from which these were taken (in the Western Australian Museum and University of Singapore), that Gibson-Hill kept this distinction largely because the bill measurements given by Mathews were mistakenly accepted as those of the exposed culmen. Mathews also gave culmen measurements for *rubricauda,* and these were similar to those Gibson-Hill made on *westralis.* The small bill of three birds from Goenoeng Api in the south Banda Sea (van Bemmel & Hoogerwerf 1940) and of several new birds from Christmas Island (Chasen 1933) had also been used to place these birds with *westralis.* In both instances the wing measurements were considered unsuitable for distinguishing *westralis* from *rubricauda* because of considerable overlap.

By comparing larger samples from the western and eastern Indian Ocean I have shown that there is no significant difference in those characters that were used to establish *rubricauda* and *westralis* as separate subspecies. Because my culmen and wing measurements were taken from live specimens as well as skins, they may be biased. However, Table 5 demonstrates that the mean measurements for skins are not significantly different ($P > 0.05$ in all four comparisons) from those made on live birds.

TABLE 5 — A comparison between measurements made on skins and live birds from the Indian Ocean

		westralis		*rubricauda*	
		Culmen	Wing	Culmen	Wing
Live	$\bar{x}$	64.71 ± 0.46	334.48 ± 1.86	64.30 ± 0.6	337.29 ± 1.56
	SD	3.06	12.50	2.90	6.42
	n	44	45	19	17
Skin	$\bar{x}$	65.02 ± 0.64	333.32 ± 1.60	65.3 ± 0.5	333.23 ± 1.71
	SD	3.02	7.52	2.8	8.71
	n	22	22	26	26
	t	0.39	0.47	1.64	1.75
	P	>0.1	>0.1	>0.1	>0.05

Certainly, the intensity of the pink suffusion in both the body and wing feathers does vary between the two subspecies. However, three factors make this character alone inadequate to support the continued differentiation of the two populations in the Indian Ocean:

1. The pink suffusion is in part a condition of new plumage and the birds' age. As it fades during the breeding season (Fleet 1974), the time of the year as well as the birds' maturity when collected would need to be known to make comparisons valid.
2. In most museums the pink suffusion does not last for more than a few years. I have seen this when comparing skins from the same islands in different museums.
3. I am not able to assign to a particular subspecies those birds taken at sea in the Indian Ocean with only slight or no suffusion. Moreover, birds collected at sea need not be breeding in the area of collection. A bird banded by Jenkins (1969) north-east of Sumatra in May 1965 was recovered near Mauritius in September 1968. Thus, the range of one "subspecies" includes the breeding islands of the other "subspecies". Because of the distance this bird had travelled (4344 km), one could not even be sure that such birds had bred in the Indian Ocean at all.

If none of the three diagnostic characters originally used to separate *rubricauda* and *westralis* are reliable, the continued use of the trinomials is unwarranted.

P. r. rothschildi, P. r. melanorhynchos and P. r. roseotincta

Whereas Mathews and Rothschild were incorrect in dividing the Indian Ocean population into two subspecies on the basis of few specimens, they were correct in stating that the Hawaiian birds (*rothschildi*) were distinguishable from those found in the Kermadec, Norfolk, Lord Howe and Raine Islands (*roseotincta*). Rothschild (1900) stated, on the basis of 28 skins from the Kermadec Islands and 15 from Hawaii, that those from the Kermadecs (he also included those from Norfolk and Lord Howe Islands) had more rosy-red tinge in their plumage as well as longer bills and wings than the Hawaiian birds.

However, no matter how different the Hawaiian and south-west Pacific birds are, they cannot be valid subspecies if the two populations grade into a continuous cline (Monroe 1982, O'Neill 1982). When Mathews (1914-15) defined the geographical distribution of *melanorhynchos* in the central Pacific as being between that of the other two subspecies, he did express caution. He did this, however, because the topotypic examples were not available for comparison, not because he was aware that they might form part of a long series of slightly different adjoining populations.

Gmelin (1789) based his type description for *melanorhynchos* on birds from Turtle (Christmas Island, Pacific Ocean) and Palmerston Islands. Mathews (1914-1915) noted that the Society Islands were geographically the nearest to Palmerston and Christmas Islands and inferred that birds from the Society Islands should belong to *melanorhynchos*. Society Island birds have ever since been accepted uncritically as *melanorhynchos*. Common usage has subsequently included birds from Austral, Ducie, Tonga, Tuamotu, Samoa, Marquesas, Phoenix, Line, and the Cook Islands under *melanorhynchos*.

The earliest hint of a cline was by Gould *et al.* (1974), who noted that the size of *rubricauda* taken in the northern Pacific tends to correlate with latitude north, being smaller from the equator northwards. What they did not realise was that the cline continued south of the equator as well. One logical expectation would be that culmen and wing would become smaller also for birds found at increasing distances south of the equator. However, this is not so, for the birds from the equator southwards continue to increase in size. Thus, genetic factors or different environmental factors in the Southern Hemisphere may produce larger birds. A similar trend has been found in the White Tern (*Gygis alba*), which breeds over a similar latitudinal range in the Indo-Pacific (Holyoak & Thibault 1976). Those breeding populations of the White Tern fitting into the cline have been united as one subspecies.

The continuous nature of the clinal gradients in both wing and culmen for individual island populations are clearly shown in Figures 1 and 2. In addition there are significant correlations between latitude and wing length ($r = 0.93$, $P < 0.001$, $n = 15$) and latitude and culmen length ($r = 0.78$, $P < 0.001$, $n = 15$).

As the correlations vary inversely with latitude in the Northern Hemisphere and proportionally with latitude in the Southern Hemisphere, Bergman's rule (Mayr 1956) on size related to heat conservation cannot apply. The continuous nature of the cline across the equator suggests gene flow is implicated.

For the White Tern, Holyoak & Thibault (1976) explained exceptions to the size cline by colony or island size; presuming that competition for nests favoured larger birds on larger islands. Increased density in the nesting colony or in the feeding ground is the more likely factor, rather than island size itself. That this is not a contributing factor in the size cline of the Red-tailed Tropicbird is suggested by the significant inverse correlations between wing size and colony size ($r = 0.69$, $P < 0.005$, $n = 16$) and culmen length and colony size ($r = 0.67$, $P < 0.005$, $n = 16$).

Another contributing factor might be the amount of available food. However, if a larger colony depletes its food supply, which in turn decreases bird size, how does the colony become so large in the first place?

In spite of the marked north-south size cline there does not appear to be an east-west cline. Two explanations are plausible:

1. The birds tend to disperse further along latitude than along longitude. The measurements from a large sample of Red-tailed Tropicbirds taken at sea, far from the nearest island, correlate with those expected for the latitude at which they were found (Gould *et al.* 1974). It is also supported by the recovery of a Red-tailed Tropicbird in the western Indian Ocean that had been banded in the eastern Indian Ocean (Jenkins & Robertson 1969).
2. The birds seem to return to their natal breeding sites. Most breeding birds return to the same nests at Kure (Fleet 1974), Sugarloaf (Tarburton 1977), and Norfolk Island (Tarburton, unpubl.).

CONCLUSIONS

As all of the five "subspecies" of the Red-tailed Tropicbird are clearly part of a north-south cline and cannot be separated from adjacent subspecies, there is no valid reason for continued use of the trinominals. The origin of this north-south cline is not clear. Evidence for considerable gene flow in the east-west direction and little gene flow along the north-south cline indicates that the cause of the cline might be genetic, although environmental factors cannot be ruled out.

ACKNOWLEDGMENTS

I thank the ornithologists at the following institutions for providing measurements: Academy of Natural Sciences; American Museum of Natural History; Auckland Institute and Museum; Australian Museum; Bernice P. Bishop Museum; British Museum of Natural History; California Academy of Sciences Museum; Carnegie Museum; Denver Museum of Natural History; Field Museum of Natural History; Los Angeles County Museum of Natural History; Museu e Laboratorio Zoologico e Antropolocico Lisboa; Museum of Comparative Zoology, Harvard University; Museum National d'Histoire Naturelle, Paris; Museum of Vertebrate Zoology, University of California; National Museum of Natural History, Smithsonian Institution; National Museum of New Zealand; National Museum of Victoria, Melbourne; Peabody Museum of Natural History, Yale University; Queensland Museum; Rijksmuseum van Natuurlijke Historie, Leiden; Royal Ontario Museum; South Australian Museum; University of Singapore; Western Australian Museum. I also thank R. Fleet, and A. W. Diamond for measurements from live birds.

LITERATURE CITED

van BEMMEL, A. C. V.; HOOGERWERF, A. 1940. The birds of Goenoeng Api. Treubia Deel 17: 421-472.

BODDAERT, P. 1783. Tabl. Planch. Enlum. 57.

CHASEN, F. N. 1933. Notes on the birds of Christmas Island, Indian Ocean. Bull. Raffl. Mus. 8: 77-79.

DIAMOND, A. W. 1975. The biology of tropicbirds at Aldabra Atoll, Indian Ocean. Auk 92: 16-39.

FLEET, R. R. 1974. The Red-tailed Tropicbird on Kure Atoll. Ornith. Monog. 16. Am. Ornithol. Union.

GIBSON-HILL, C. A. 1950. Notes on the birds of the Cocos-Keeling Islands. Bull. Raffles Mus. 22: 249-251.

GILL, F. B. 1982. Commentary. Avian subspecies in the 1980's - *Might there be a resurrection of the subspecies?* Auk 99: 598-599.

GMELIN, L. 1789. Syst. Nat. 1: 582.

GOULD, P. J.; KING, W. B.; SANGER, G. A. 1974. Red-tailed Tropicbird (*Phaethon rubricauda*). *In* King, W. B. (Ed.) Pelagic studies of seabirds in the central and eastern Pacific Ocean. Smithsonian Contribution to Zoology 158: 206-277.

HINDWOOD, K. A.; KEITH, K.; SERVENTY, D. L. 1963. Birds of the South-west Coral Sea. Division of Wildlife Research Technical Paper No 3, C.S.I.R.O. Melbourne.

HOLYOAK, D. T.; THIBAULT, J. -C. 1976. La variation géographique de *Gygis alba*. Alauda 44: 457-473.

JENKINS, J.; ROBERTSON, C. J. R. 1969. Banding recovery - Red-tailed Tropic Bird. Notornis 16: 211.

MATHEWS, G. M. 1912. Austral Avian Record 1: 88.

MATHEWS, G. M. 1914-15. *Birds of Australia.*

MAYR, E. 1956. Geographic character gradients and climatic adaptation. Evolution 1: 105-108.

MAYR, E. 1982. Commentary. Avian subspecies in the 1980's - Of what use are subspecies? Auk 99: 593-595.

MONROE, B. L. 1982. Commentary. Avian subspecies in the 1980's - A modern concept of the subspecies. Auk 99: 608-609.

O'NEILL, J. P. 1982. Commentary. Avian subspecies in the 1980's - The subspecies concept in the 1980's. Auk 99: 609-612.

PETERS, J. L. 1931. Check-list of Birds of the World. Vol. 1. Cambridge, Massachusetts: Harvard Uni. Press.

ROTHSCHILD, W. 1900. *The avifauna of Laysan and the neighboring islands; with a complete history* to date of the Hawaiian possessions. Part 111. London: R. H. Porter.

TARBURTON, M. K. 1977. Nesting of the Red-tailed Tropicbird at Sugarloaf Rock, W. A. Emu 77: 122-126.

M. K. TARBURTON, *Department of Botany and Zoology, Massey University, Palmerston North*

SHORT NOTE

Copulation in the Yellow-eyed Penguin

To date copulation in the Yellow-eyed Penguin *(Megadyptes antipodes)* has not been recorded, despite the long-term work of L. E. Richdale, who studied the Yellow-eyed at colonies in the South Island: " . . . on my many visits to the nests of the Yellow-eyed Penguin in the ten years when I observed them, I never witnessed coition, although I had been present at night as well as in the daytime" (Richdale 1957:27).

During a study of the breeding behaviour of the Yellow-eyed Penguin I have once observed copulation by a banded pair, from a hide about 20 m away.

On 20 September 1985 at about 1800 h, both birds were upright near the nest bowl. The male began the behaviour by approaching the female in a "shoulders hunched" attitude, as described for the Erect-crested Penguin by Warham (1975). The female moved away from the male, also in a "shoulders hunched" posture. The male followed, and both birds circled the nest twice before the female stopped upright, back to the male, in the nest bowl. The male then walked up to the female's back and began the "arms act" (Richdale 1951), rapidly vibrating his flippers against the female's sides. As the female remained upright, the male leaned forwards and preened the female's neck. Either voluntarily or due to the pressure being exerted by the male, the female adopted a prone posture; feet braced backwards, flippers extended to the sides, tail vertical, cloaca everted, neck upright, and head and beak firmly horizontal. The male continued to beat lightly with his flippers and nibble preen the female's crown, while climbing on to the centre of her back. The female maintained her position as the male trod slowly backwards, all the time vibrating his flippers and preening the female. With his body bowed over the female's, the male lowered his tail until their cloacas were held briefly together. Immediately afterwards the male dismounted and began to preen. The female remained prone for another minute before standing up and preening also. From the approach of the male to dismount, the whole sequence took 110 s.

I saw no further copulation attempts although I made daily visits to the nest. The first egg was laid after 12 days on 2 October and the second was laid 4 days later. Both eggs hatched after an incubation span of 42 days. Two chicks fledged at about 105 days.

Copulation in other penguins: The form of copulation here described for the Yellow-eyed Penguin is essentially the same as that recorded for the other penguins. There was some minor differences : Tail-wagging by the male during cloacal positioning was not noticed in the Yellow-eyed but is a feature of Jackass Penguin copulation (Eggleton 1979). Female head position when prone was beak horizontal in the Yellow-eyed, whereas the head of the female Adélie Penguin is raised (Spurr 1975). Immediately after coition a special attitude is adopted by the male Royal Penguin (Warham 1971) and the male Erect-crested Penguin (Warham 1972), which turn their head down and withdraw their beak. No such post-coital posture was observed for the male

Yellow-eyed Penguin. Because I saw only one complete copulation, however, these differences may not be real.

It is a reflection of the secretive nature of the Yellow-eyed Penguin that, despite breeding close to the activities of humans, such a basic behaviour as copulation has not previously been observed.

I thank Lloyd Davis and Yolanda van Heezik for their useful comments on this note and John Darby for his help in the field.

LITERATURE CITED

EGGLETON, P. ; SIEGFRIED, W. R. 1979. Displays of the Jackass Penguin. Ostrich 50:139-167.
RICHDALE, L. E. 1951. Sexual Behaviour in Penguins. Lawrence : University of Kansas Press.
RICHDALE, L. E. 1957. A Population study of Penguins. Oxford : Clarendon Press.
SPURR, E. B. 1975. Communication in the Adelie Penguin. *In* The Biology of Penguins (B. Stonehouse, ed.). London : Macmillan.
WARHAM, J. 1971. Aspects of breeding behaviour in the Royal Penguin *Eudyptes chrysolophus schlegeli.* Notornis 18:91-115.
WARHAM, J. 1972. Aspects of the biology of the Erect-crested Penguin *Eudyptes sclateri.* Ardea 60:145-183.
WARHAM, J. 1974. The Fiordland Crested Penguin *Eudyptes pachyrhynchus.* Ibis 116:1-23.
WARHAM, J. 1975. The crested penguins. *In* The Biology of Penguins. (B. Stonehouse, ed.). London: Macmillan.

PHILIP SEDDON, *Department of Zoology, University of Otago, P.O. Box 56, Dunedin*

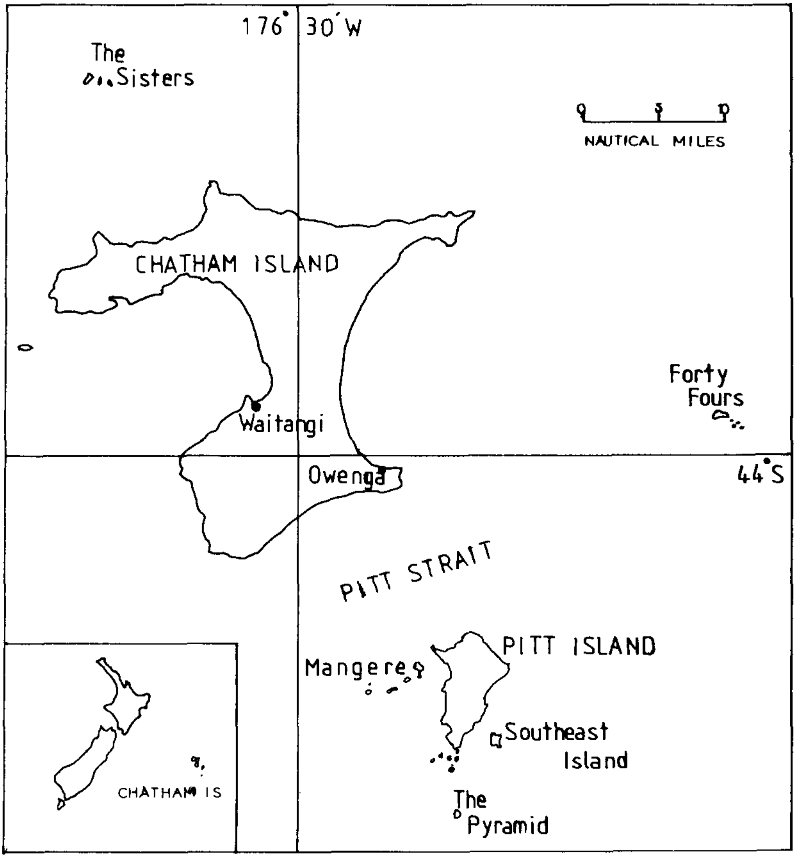
★

Cape Pigeons breeding and Westland Black Petrels seen at Chatham Islands

On 2 December 1983, M.J. Imber saw a Cape Pigeon *(Daption capense)* fly off a cliff ledge on the northern side of the main island of the Forty Fours, Chatham Islands (Imber, pers. comm.). In November and December 1987, SRV *Totorore,* while assisting with the Taiko research project, visited the Forty Fours and confirmed that the Cape Pigeon is breeding there.

Ten pairs of Cape Pigeons were seen on the four stacks to the eastward of the main island of the Forty Fours and three pairs on the cliff ledges on the main island itself. A landing was made on the third stack from seaward on 28 November, and Roger Mayhill, using ropes and climbing gear, was able to reach the summit, where he watched and photographed the change-over between a pair of Cape Pigeons incubating an egg.

On 2 December 1987, three pairs of Cape Pigeons were seen occupying ledges near the summit of the Pyramid. At the Sisters, about 40 Cape Pigeons were seen flying close around the islands, but none landed there during our visits.



Several probable sightings of Westland Black Petrel *(Procellaria westlandica)* in association with White-chinned Petrel *(P. aequinoctialis)* were made in Pitt Strait during November and December. On 13 December 1987, Harro Müller positively identified two *P. westlandica* in attendance on a trawler near Owenga. Three days later, two more of the same species, again in loose association with *P. aequinoctialis*, were identified from *Totorore* about 20 miles south-west of Pitt Strait, having been attracted close by means of fish bait. With the difficulty of separating the two species at sea, it is possible that *P. westlandica* may habitually be present around these islands at this time of year without being noticed.

I thank all who helped, particularly Mike Imber, Harro Müller, Roger Mayhill, Julia von Meyer and Adrian Plant. I thank Anthea Goodwin for preparing the map.

G.S. CLARK *Homelands Organic Orchard, Kemp Road, Kerikeri*

ORNITHOLOGICAL OBSERVATIONS AT EDWARD VII PENINSULA, ANTARCTICA, IN 1987-88

By P. A. BROADY, C. J. ADAMS,
P. J. CLEARY and S. D. WEAVER

INTRODUCTION

During a geological expedition to Edward VII Peninsula (78°45'S, 154°W), Marie Byrd Land (Fig. 1), between 28 November 1987 and 12 January 1988, we took the opportunity to make wide-ranging biological observations and collections. Reported here are the ornithological observations. Our expedition travelled over 500 km by sledge and motor toboggan, visiting all the nunataks in the Alexandra and Rockefeller Mountains. Our travel route between nunataks is shown in Fig 2. During a reconnaissance overflight on 25 November, the coastline was surveyed from a height of about 700 m.

There have been few expeditions to Edward VII Peninsula. The region was discovered by the British National Antarctic Expedition 1901-1904, which made the first bird observations offshore (Scott 1905, Wilson 1905). A party from Amundsen's expedition 1910-1912 was the first to reach ice-free land in the Alexandra Mountains (Amundsen 1912), but the Rockefeller Mountains were not visited until 18 years later by a party from the 1st Byrd

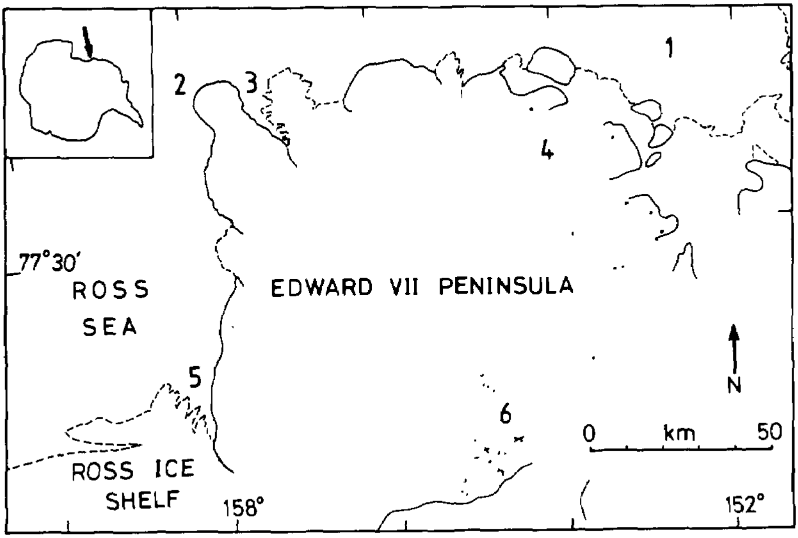


FIGURE 1 — Edward VII Peninsula. 1. Sulzberger Bay. 2. Cape Colbeck. 3. Bartlett Inlet. 4. Alexandra Mountains. 5. Okuma Bay. 6. Rockefeller Mountains. Dashed line = coastline of ice-shelves and glaciers. Nunataks are marked in the Alexandra and Rockefeller Mountains. Inset locates Edward VII Peninsula on the Antarctic Continent

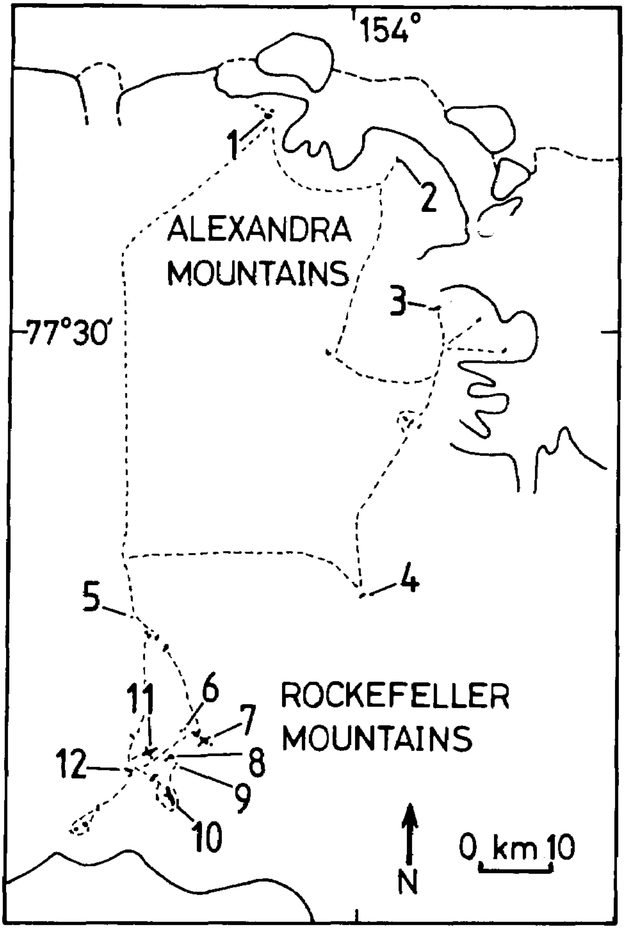


FIGURE 2 — Nunataks of the Alexandra and Rockefeller Mountains. 1. Scott Nunataks. 2. Mt Swadener. 3. Bowman Peak. 4. Drummond Peak. 5. Mt Frazier. 6. Melbert Rocks. 7. Mt Paterson. 8. Mt Schlossbach. 9. Fokker Rocks. 10. Washington Ridge. 11. Mt Nilsen. 12. Breckinridge Peak. Dashed line = sledging route of the expedition

Antarctic Expedition 1929-1930. However, the first attempts at detailed observations on birds in the region were made by the 2nd Byrd Antarctic Expedition 1933-1935 (Siple & Lindsey 1937) and the United States Antarctic Service Expedition 1939-1941 (Friedmann 1945, Perkins 1945). No further observations on birds have been made.

DESCRIPTION OF THE REGION

Edward VII Peninsula is almost covered by ice-fields and glaciers (Fig. 1). The seven nunataks of the Alexandra Mountains and the 16 nunataks of the Rockefeller Mountains are the only ice-free land, comprising a small fraction of 1% of the total area (Fig. 2). There are no coastal rock outcrops. The coastline is entirely ice-cliffs of ice-shelves, glacier tongues and ice-covered land. Summits of nunataks range from about 419 m to 1174 m altitude and, except close to the coast, the surrounding ice-surfaces have an elevation of 400 m to over 1000 m. The most extensive nunataks are in the Rockefeller Mountains, where they are mostly low ridges up to about 3 km long. Ice-free rock in the Alexandra Mountains is much less extensive and is mostly steep slopes and cliffs of two north to north-east facing escarpments. A general description of the region was provided by Wade (1945) and a 1:250 000 map is available (USGS 1972).

During our period in the field, which covered early to mid-summer, the air temperature ranged from -17 to -2 °C and was usually from -10 to -3 °C. There was a high proportion of overcast and windy days but wind speeds did not exceed 20 knots.

OBSERVATIONS AND DISCUSSION

ANTARCTIC PETREL (*Thalassoica antarctica*)

The major ornithological find of the expedition was the location and size of the nesting colony of Antarctic Petrels on Mt Paterson (Fig. 2 - 5). The US Antarctic Service Expedition discovered a colony there and collected eggs (Perkins 1945, Friedmann 1945), but they did not give its size. We had previously observed numerous birds flying around the southernmost peak (Fig. 4) through binoculars from Mt Schlossbach, 7 km distant. However, we were unprepared for the spectacular sight of close-packed nest sites, 1-2 m apart (Fig. 5), covering most of the eastern, southern and western lower slopes of this peak. As the colony stretched about 50 m upslope from the ice edge and 400 m around the peak at ice level, we estimated it to occupy

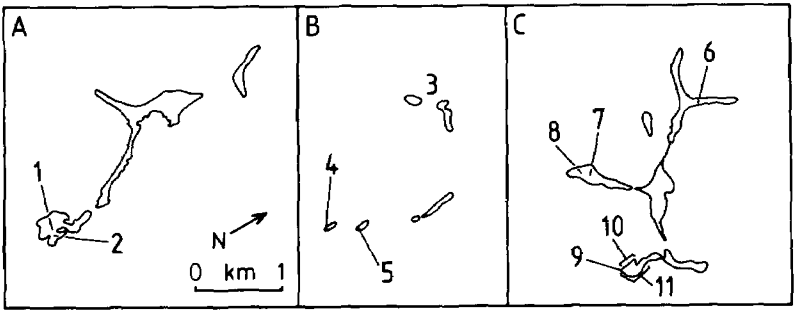


FIGURE 3 — Locations of breeding birds and other observations at the Rockefeller Mountains (see text for details). A, Washington Ridge; 1, three to four empty skua nest bowls at summit of southermost peak; 2, small colony of Snow Petrels on east-facing slope. B, Fokker Rocks; 3, Mt Schlossbach; 4, skua perch on boulder at southern end of Fokker Rocks; 5, pair of nesting skuas. C, Mt Paterson; 6, three to four empty skua nest bowls; 7, small colony of nesting Snow Petrels; 8, Pair of skuas with two chicks; 9, pair of skuas with one chick; 10 and 11, slopes occupied by the large colony of Antarctic Petrels on the southernmost peak

4

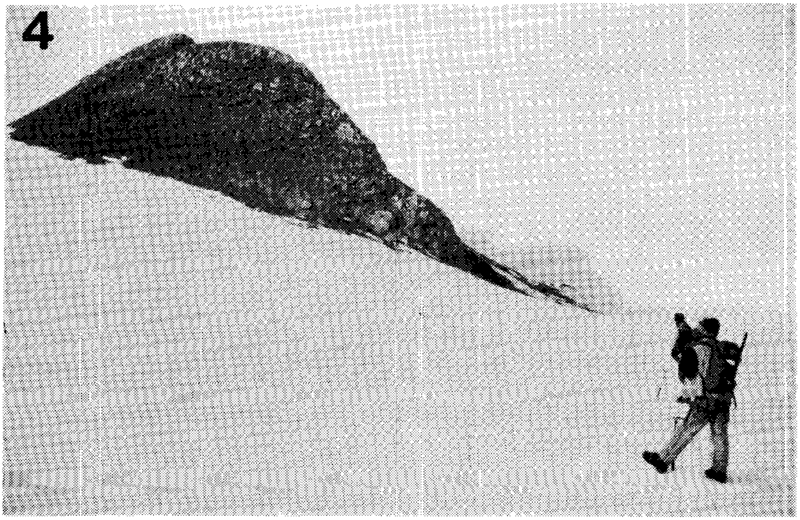


FIGURE 4 — The southernmost peak of Mt Paterson (see Fig. 3C for location) viewed from the north-west from about 0.5 km. The lower slopes shown and those on the other side of the peak supported the large colony of Antarctic Petrels. Snow Petrels nested on the steeper bluffs towards the summit of the peak, and a pair of breeding skuas occupied a site close to the right-hand extremity of the slopes in this view

5

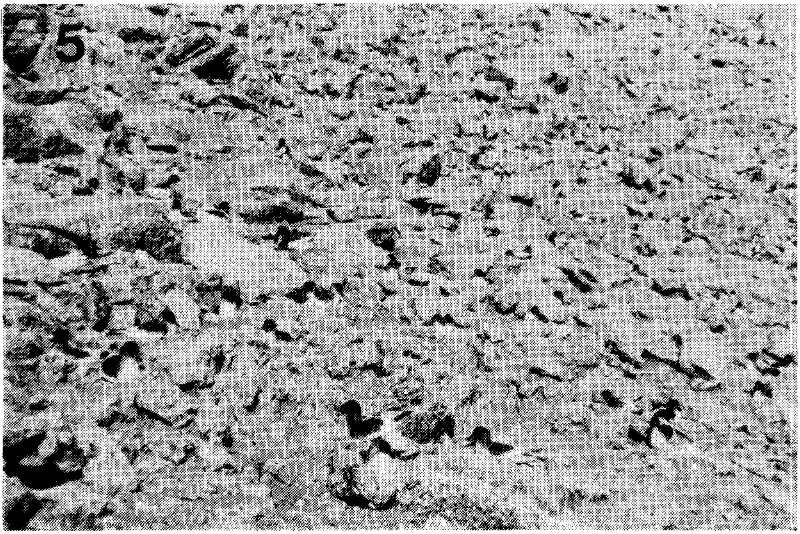


FIGURE 5 — A general view of the Antarctic Petrel colony on the south-facing slope of the southermost peak of Mt Paterson (see Fig. 4). Most nests are attended by single birds and the nests are all in exposed positions on the guano-covered slopes

1-2 ha. The birds occupied exposed positions on the stable scree-slopes. The ground between the nests was covered by guano, feathers and broken eggshells. Towards the bottom of the slopes and close to melting snowdrifts were large growths of the nitrophilous green alga *Prasiola crispa*, which thrived on the guano. Many of the birds were sitting on eggs (29 December) but we saw no chicks. We could not make detailed counts, having only about two hours at the colony. However, by counting birds in a small area and extrapolating to the entire nesting area, we estimated that about 10 000 birds were on the southern to eastern slopes and 5000 on the western. As a large proportion of nests had only a single bird attending, we estimate a total of roughly 10 000 nest sites. This is relatively few compared with colonies elsewhere, for example, the 207 000 nesting pairs reported from Dronning Maud Land by Mehlum *et al.* (1987).

We found no evidence for other breeding sites. We saw surprisingly few birds during our travels, and only on 8 days of the 46 days in the field, of which only two were in the Alexandra Mountains. The largest flock seen away from the colony was one of 15 birds over Mt Nilsen. We may only rarely have crossed their main route to open-water feeding grounds, the closest of which were 85 km west to north-west of the colony near Okuma Bay (Fig. 1). Birds at colonies elsewhere in Antarctica are known to fly even further to their feeding grounds, for example, at least 200 km by birds from the Dronning Maud Land colony (Mehlum *et al.* 1987).

Members of the British National Antarctic Expedition observed "very large numbers ... in a very local area about King Edward's Land" (Wilson 1905) when they were sailing in that region. Wilson made the perceptive comment that "a search for the nesting grounds might quite possibly be well repaid". It was not until the 2nd Byrd Antarctic Expedition that Antarctic Petrels were seen in the Rockefeller Mountains. Siple & Lindsey (1937) estimated about 500 in a mixed flock of Antarctic and Snow Petrels flying around Washington Ridge and thought nesting likely there. However, we found only a few Snow Petrel nests. The only other definite breeding site in the Ross Sea region is in the far north at the Balleny Islands, although Scott Island and Robertson Bay are possible sites (Harper *et al.* 1984).

SNOW PETREL (*Pagodroma nivea*)

In the Rockefeller Mountains we found nesting Snow Petrels on two nunataks, Washington Ridge and Mt Paterson (Fig. 2 and 3). The colony on the upper, east-facing slopes of the southernmost peak on Washington Ridge was small with only 12 occupied nests, and 4 unoccupied, one with an apparently abandoned egg. We saw only a small group of 5 birds flying above the peak.

We found the major Snow Petrel nesting area to be at Mt Paterson. On 29 December, we found a small group of 11 nests with birds on eggs close to the ridge crest in the middle of the more northerly of the two south-west projecting ridges. However, on the steep upper crags of the southernmost peak, above the extensive Antarctic Petrel colony, several hundred birds were nesting. The crags were inaccessible, but birds were flying on and off ledges and white streaks of guano were visible on the rocks.

Snow Petrels were seen on 23 of the 46 days in the field, varying from single birds passing over campsites to hundreds around the nesting colony on the southernmost peak of Mt Paterson (Fig. 3 and 4). Elsewhere in the Rockefeller Mountains, the largest flock seen was 100 birds over Melbert Rocks (Fig. 2). In the Alexandra Mountains, the most seen together were about 15 birds overflying Bowman Peak (Fig. 2). Birds were also seen in the air during periods of white-out when we were confined to our campsites.

In the Alexandra Mountains, we did not find nesting birds, although we saw small groups of petrels, up to 15, flying around each of the seven nunataks. We could, however, have missed small numbers of nest sites on inaccessible areas of rock. Birds were also seen around nunataks in the Rockefeller Mountains where we were certain there were no nests, e.g. a flock of up to 15 birds around Drummond Peak (Fig. 2). At Scott Nunataks (Fig. 2) we found fragments of white eggshells below stones close to the summit of the small knoll at the base of the main rock exposure, and immediately north of it. Measurements on these indicate that they are probably fragments of Snow Petrel eggs (G. Tunnicliffe, pers. comm.).

It seems likely that the shell fragments found at Scott Nunataks were exactly the same "remains of birds' nests" as found by the Eastern Party of Amundsen's Expedition led by Prestrud (Amundsen 1912), when they were first to reach ice-free land on Edward VII Peninsula.

A previous record of "about 100 nests" on Breckinridge Peak in the Rockefeller Mountains (Tanner 1941 cited by Friedmann 1945) was not confirmed. We found no evidence of a nesting colony on the "north exposed side of the mountain", an observation ascribed by Tanner to Frazier, of the US Antarctic Service Expedition 1939-41.

Siple & Lindsey (1937) suggested that the southernmost peak on Washington Ridge was the location of a large colony. They described a flock of about 1000 birds enveloping the summit, comprising approximately equal numbers of Snow and Antarctic Petrels. Although they found birds on eggs they did not estimate nest numbers. However, Byrd (1936), in his general narrative of that expedition, mentioned that only "...one hen nesting" was encountered. The US Antarctic Service Expedition collected Snow Petrel specimens at both Washington Ridge and Mt Paterson (Perkins 1945, Friedmann 1945). Neither author gave colony sizes, although Friedmann noted that eight eggs were collected at Washington Ridge.

The Rockefeller Mountain breeding areas were not included by Harper *et al.* (1984) but they noted three sites in the eastern ranges of Marie Byrd Land to the east of Edward VII Peninsula.

WILSON'S STORM PETREL (*Oceanites oceanicus*)

Three solitary birds were seen flying over snowfields close to Mt Swadener and Scott Nunataks in the Alexandra Mountains and near our final campsite, 10 km north-east of Mt Frazier in the Rockefeller Mountains (Fig. 2). The three locations were respectively 11, 11 and 75 km from the closest open water.

Previous expeditions had seen Wilson's Storm Petrels over the Ross Ice Shelf, west of Edward VII Peninsula (Siple & Lindsey 1937, Perkins 1945). It is not unusual to find birds a long way from the closest open water.

Wilson (1907) reported birds flying over the Ross Ice Shelf some 96 km from open water.

This region of Marie Byrd Land has no known breeding sites (Harper *et al.* 1984). The closest known site is on Franklin Island (76°10'S, 168° 20'E) about 900 km to the west-north-west.

SOUTH POLAR SKUA (*Stercorarius skua*)

Nesting skuas were found at three locations (Fig. 2 and 3). On the middle group of Fokker Rocks, a pair was incubating eggs at the southern end of the rock exposure on 24 December. On Mt Paterson we found two pairs with chicks on 29 December. One pair with two young chicks in down occupied a ridge crest site close to a small group of Snow Petrel nests. The second pair had a single, larger, more mobile, unfledged chick. Their site was at the southernmost extremity of Paterson Ridge at the base of the peak which supported the large Antarctic Petrel colony on its lower slopes (Fig. 4). On the ice slopes beside the nest site were the remains of over 20 recently killed Antarctic Petrels. The summit ridge of this peak may have had another skua nest as two more birds were seen flying above the peak, but we did not traverse the ridge. In Dronning Maud Land, Mehlum *et al.* (1987) observed 50 pairs of breeding skuas around a large Antarctic Petrel colony, with a ratio of about one pair to 4000 pairs of petrels. This is perhaps a smaller ratio than that of about one to 7000 - 15 000 pairs at the Rockefeller Mountains rookery.

Evidence of skua feeding and breeding activities was seen on nine rock outcrops in the Rockefeller Mountains in addition to those noted above, but only at Scott Nunataks (Fig. 2) in the Alexandra Mountains. This comprised the rare find of dried and bleached bones of Snow Petrels and Antarctic Petrels or equally rare dried feeding pellets containing feathers and bones. Unoccupied nest sites, consisting of shallow scraped bowls in gravel and surrounded by sparse scatterings of bones and feeding pellets, were found on the summit of the southernmost peak of Washington Ridge and on Mt Paterson, about 2 km north-west of the petrel colonies (Fig. 3). Each location had 3-4 nest bowls, probably constructed by the same pair of skuas. On Washington Ridge one nest contained the desiccated carcass of a young chick in down.

Skuas were observed on 13 of the 46 days spent in the field, five in the Alexandra Mountains and eight in the Rockefeller Mountains. These birds were flying over while we were travelling or were seen at our campsites. Nine times they were single birds, four times pairs, and three times trios. Several sightings may have been of the same birds.

From these observations we believe that no more than 30 adult skuas were in the whole region visited, including in 1987-88 no more than four breeding pairs. This total is probably an overestimate as undoubtedly the same birds were seen on two or more occasions.

A party from the 1st Byrd Antarctic Expedition was the first to record skuas in the region when three visited their camp below Washington Ridge (Gould 1930). Siple & Lindsey (1937) saw perhaps the same birds five years later flying around the Snow Petrel rookery at Washington Ridge. As the nests there have been abandoned skua numbers could be fewer than 50 years ago. Two eggs were collected at Mt Paterson by the US Antarctic Service Expedition (Friedmann 1945, Perkins 1945). In their review Harper *et al.* (1984) omitted Edward VII Peninsula as a breeding area.

EMPEROR PENGUIN (*Aptenodytes forsteri*))

During the reconnaissance flight on 25 November, we checked the fast ice along the coastline for Emperor Penguins. Fast ice and heavy pack-ice stretched northwards to the horizon. By this date, any colony should not have dispersed. In particular, we wanted to check Bartlett Inlet (Fig. 1; 77°15′S, 157° 20′E), where a colony is marked on the 1:500 000 USGS sketch map of the Saunders Coast (1968). The plane stayed at about 700 m from Howard Heights (77°15′S, 151° 40′W) to the tip of Cape Colbeck (77°10′S, 158°W), following the northern edge of the ice-shelf and ice-covered land (Fig. 1). Only west of Cape Colbeck did low cloud prevent us from looking for penguins. We saw no penguins even though visibility was good along the coastline examined and we could clearly see seals with pups.

Despite the lack of sightings from the air, an intriguing observation was made at Scott Nunataks (Fig. 2). On the low rocky knoll immediately north of the main outcrop we found a scattering of some hundreds of penguin feathers caught up among a square metre of abundant growths of the "bushy" lichen *Usnea antarctica*. When G. Tunnicliffe matched these feathers against study skins of antarctic penguins, he found the closest similarity with the Emperor Penguin. The feathers cannot be dated but look in good condition. The most likely explanation is that a bird wandered inland to moult at this location, 11 km from the coast. These birds have been seen inland before. For example, Siple & Lindsey reported tracks 24 km from the coast of the Ross Ice Shelf.

Emperor Penguins in Sulzberger Bay have often been seen from ships (Scott 1905, Wilson 1905, Perkins 1945), but a colony has not been confirmed (Harper *et al.* 1984). Wilson (1905) at first considered the "groups of hundreds of the birds all huddled together in enormous colonies" to be breeding but on later consideration concluded that they were "simply moulting". We are confident that there was no colony at Bartlett Inlet or elsewhere along the route of our reconnaissance. However, a colony could exist south of Cape Colbeck in the vicinity of Okuma Bay or further east from Howard Heights, outside the area examined during the flight.

ADÉLIE PENGUIN (*Pygoscelis adeliae*)

We did not see Adélie Penguins during the reconnaissance flight or during the sledging journey. The Peninsula coastline is all ice and has no coastal rock outcrops for nesting colonies.

Three Adélie rookeries are known further east in Marie Byrd Land (Strandtmann 1978), the closest being at Cruzen Island (74°45′S, 140°40′W) about 550 km to the north-east. Scott (1905) reported large numbers of birds offshore from the Alexandra Mountains in Sulzberger Bay, and Perkins (1945) reported one captured on the Ross Ice Shelf "near the Rockefeller Mountains and at least 45 miles from the nearest open water".

ACKNOWLEDGEMENTS

We gratefully acknowledge the logistic support of Antarctic Division, DSIR, and the US Navy VXE6 Squadron. G. Tunnicliffe, Canterbury Museum, identified ornithological materials. E. Young, University of Auckland, and P. C. Harper, University of Canterbury, gave constructive criticism of the manuscript.

LITERATURE CITED

AMUNDSEN, R. 1912. The South Pole. London: John Murray.

BYRD, R. E. 1936. Antarctic Discovery. London: Putman

FRIEDMANN, H. 1945. Birds of the United States Antarctic Service Expedition 1939-41. Proc. Am. Phil. Soc. 89: 305-313.

GOULD, L. M. 1930. Cold, the record of an Antarctic sledge journey. N.Y.: Brewer, Warren and Putman.

HARPER, P. C.; KNOX, G. A.; SPURR, E. B.; TAYLOR, R. H.; WILSON, G. J.; YOUNG, E. C. 1984. The status and conservation of birds in the Ross Sea sector of Antarctica. ICBP Tech. Publ. No. 2: 593-608.

MEHLUM, F.; BECH, C.; HAFTORN, S. 1987. Breeding ecology of the Antarctic Petrel *Thalassoica antarctica* in Muhlig-Hofmannfjella, Dronning Maud Land. Proc. Nat. Inst. Polar Res. Symp. on Polar Biology. No. 1: 161-165.

PERKINS, J. E. 1945. Biology at Little America III, the West Base of the United States Antarctic Service Expedition 1939-41. Proc. Am. Phil. Soc. 89: 270-284.

SCOTT, R. F. 1905. The Voyage of the Discovery. Vol. 1. London: Smith, Elder and Co.

SIPLE, P. A.; LINDSEY, A. 1937. Ornithology of the Second Byrd Antarctic Expedition. Auk 54: 147-159.

STRANDTMANN, R. W. 1978. Three Adelie Penguin colonies on the Hobbs Coast, and a nesting site of the Snow Petrel, Marie Byrd Land, Antarctica. Antarct. J. U.S. 13: 151-153.

TANNER, V. M. 1941. Antarctic birds contributed by Dr. Russell G. Frazier. Great Basin Naturalist 2: 122-124.

U.S.G.S. 1968. Antarctic sketch map. Saunders Coast - Marie Byrd Land. Scale 1:500 000. Washington D. C.: U.S. Dept. Int., Geological Survey.

U.S.G.S. 1972. Alexandra Mountains, Antarctica. 1:250 000. Washington D.C.: U.S. Dept. Int., Geological Survey.

WADE, F. A. 1945. The geology of the Rockefeller Mountains, King Edward VII Land, Antarctica. Proc. Am. Phil. Soc. 89: 67-77.

WILSON, E. A. 1905. On the whales, seals and birds of Ross Sea and South Victoria Land. Pages 469-494 *in* (Scott, R. F.) The Voyage of the Discovery. Vol. 2. London: Smith, Elder and Co.

WILSON, E. A. 1907. Aves. National Antarctic Exped., Nat. Hist. Vol. 2, Vertebrata Pt. 2: 1-21, pls. 1-13. London: Br. Mus. Nat. Hist.

P. A. BROADY, *Department of Plant and Microbial Sciences, University of Canterbury, Christchurch;* C. J. ADAMS, *Institute of Nuclear Sciences, DSIR, Lower Hutt;* P. J. CLEARY, *9 Craven Street, Christchurch;* S. D. WEAVER, *Department of Geology, University of Canterbury, Christchurch*

SHORT NOTE

Genetics of polymorphism in the Little Shag

John Dowding and Michael Taylor's paper on "Genetics of Polymorphism in the Little Shag" (*Notornis* 34 (1):51-57) is a brave effort at going beyond the mere collection of data to attempt to analyse and explain. They propose a genetic model which predicts the ratios of black and pied offspring to be expected from the various pairings of white-throated, smudgy, or pied adult birds. As the numbers they actually observed were consistent with those expected under their model they infer that their model is valid: "Our evidence supports the conclusion that plumage polymorphism in the Little Shag is controlled by two alleles at a single genetic locus, the allele specifying 'dark' being incompletely dominant."

However, it seems to me that there are defects in their analysis which seriously undermine the validity of this conclusion. One could question their assumption that the population is at genetic equilibrium when there is a gradient in morph frequencies from north to south of New Zealand, suggesting, as they point out, "that one or more selective forces are constantly in operation." But the basic problem is one of logic. Dowding and Taylor's hypothesised genetic model is a plausible one and their observed data are indeed consistent with it – or, in statistical language, not significantly different from those expected under their hypothesis. But such a finding does not necessarily mean that the hypothesis is true. Statistical hypothesis testing proceeds by a process of rejection: a hypothesis is accepted only if all possible alternatives can be rejected. I suggest that in the case of the Little Shag there are other possible alternatives which Dowding and Taylor did not test – other genetic models which are equally plausible, and which cannot be rejected on the basis of their observed data.

In particular, they could also have considered the reverse model to theirs: that 'pied' is partially dominant over 'white-throated', with all the smudgy and some of the pied birds being heterozygous (see model B in Table 1). By my calculations the expected ratios of black and pied offspring are not greatly different under either model. The expected results are given in Table 2, along with those under Dowding and Taylor's model (model A). I have

TABLE 1. Genetic models for polymorphism in the Little Shag: frequencies of hypothesised genotypes

Genotypes XX, xx = homozygous; Xx = heterozygous. Model A is basically that of Dowding and Taylor (1987); Model B its inverse.

	Model A (*Wh* partially dominant)	Model B (*Pd* partially dominant)
<u>Adult morphs</u>		
White-throated (*Wh*):	.188 XX + .324 Xx	.512 xx
Smudgy (*Sm*):	.167 Xx	.167 Xx
Pied (*Pd*):	.321 xx	.081 XX + .240 Xx

TABLE 2. — Comparison of observed frequencies of black and pied offspring of Little Shags with those expected under genetic models A and B.

Parental cross	No. of Black offspring			No. of Pied offspring		
	Obs	Exp A	Exp B	Obs	Exp A	Exp B
1. *Wh* x *Wh*	17	15.3	17	0	1.7	0
2. *Wh* x *Sm*	11	9.3	7.8	0	1.7	3.2
3. *Wh* x *Pd*	19	17.1	15.8	6	7.9	9.2
4. *Sm* x *Sm*	1	1.5	0.9	1	0.5	1.1
5. *Sm* x *Pd*	1	3.0	2.4	5	3.0	3.6
6. *Pd* x *Pd*	0	0	0.33	1	1	0.67
Totals	49	46.2	44.23	13	15.8	17.77

recalculated the latter because of the inconsistency in their method of calculating the proportion of heterozygotes among the white-throated birds. Their method implicitly assumes that there is also the same proportion of heterozygotes among the smudgy birds, but elsewhere they assume that *all* smudgy birds are heterozygotes. I have followed the latter assumption, although again the differences in the expected numbers are small. When the two models are tested against the observed results using a similar chi-squared goodness-of-fit test to that used by Dowding and Taylor (grouping results to avoid small expected numbers), in both cases the differences are not significant ($x^2 = 7.3$ and 6.6 respectively; with 6 d.f., $P > 0.50$ in both cases).

Therefore neither Dowding and Taylor's model nor the alternative model can be rejected on the basis of the observed numbers of black and pied offspring. There may well be other, more complex models which would also explain the observed pattern. More observations are required before any single genetic model for the polymorphism of the Little Shag can be unequivocally accepted.

ROSS GALBREATH, *Naike, R.D. 2, Huntly*

Galbreath raises a number of matters in his letter. First, he questions our assumption that the population is at genetic equilibrium. There are two main points to be made here; the first is that although there is little evidence either way, it does appear that the cline we describe (more pied birds in the north, more white-throated in the south) has been in place for some time. This suggests some stability in the population, if only at a gross level; hence our deliberate statement that "we have no evidence that it is not" (at equilibrium). He is probably aware by now that we are attempting to accumulate data on this question via the OSNZ Little Shag survey. This is being carried out at present and again, it is hoped, in five or ten years time. Second, morph frequencies such as those discussed here very rarely change rapidly – for the practical purposes of genetic analysis most populations are at genetic equilibrium, unless a dramatic selective force is operating. Obviously we have had to make this assumption (which we believe to be a reasonable one) or we would not have published our model.

The second matter is a somewhat philosophical one, concerning statistical hypothesis-testing. Galbreath declares that "the basic problem is one of logic". If he is suggesting that we were illogical in putting forward the conclusion we did, then I must disagree with him. He states that "a hypothesis is accepted only if all possible alternatives can be rejected". This suggests, incorrectly in my view, that our model cannot stand as a *hypothesis* until all others have been considered. This may be the case for a *theory* but it is clearly not accepted practice for testing hypotheses in the biological sciences. We have put forward for discussion a hypothesis (which is consistent with the known facts) and it remains valid until disproved.

Third, he points out an error in our calculation of the proportion of heterozygotes among white-throated birds, for which I am grateful. The equations shown (our paper, p.54) should read:

$$DD/DD + Dd = 0.19 / 0.19 + 0.32 = 0.37$$

$$Dd / DD + Dd = 0.32 / 0.19 + 0.32 = 0.63$$

The expected values of black and pied offspring in our Table 3 therefore become 17.1 and 7.9 respectively (as shown in Galbreath's Table 2, Exp A). This makes our expected and observed results for Wh x Pd crosses slightly closer and causes no change to our conclusions.

Fourth (and most significant), Galbreath proposes an alternative model in which 'pied' is partially dominant over 'dark'. He calculates expected numbers of black and pied offspring and shows (his Table 2) that his model is as valid *statistically* as ours. In doing this, however, he makes an additional assumption which I believe renders his model less likely than ours. In our paper, we showed that it is probable that black juveniles develop into both white-throated and smudgy adults, with pied juveniles developing into pied adults. Galbreath has clearly accepted this in calculating his expected values (Exp B) in Table 2; he assigns his heterozygous offspring to the black and pied categories in the proportion 0.167 / 0.407 black: 0.240 / 0.407 pied (heterozygote frequencies from his Table 1). However, this results in a situation where some heterozygotes must develop into black chicks (and become smudgy adults) and others must develop into pied chicks (and pied adults). Thus individuals of the same genetic constitution would be required to display two distinctly different juvenile phenotypes. Some explanation as to how this might occur is necessary (none is provided) and I suspect it would result in a much more complex model. The situation proposed in our model, in which all heterozygotes develop into black chicks, seems the more likely.

Finally, Galbreath suggests that there may be other, more complex models which would explain our observations. I agree, and I am sure the situation is indeed more complicated than either of us has suggested – for this very reason we stated in the Discussion of our paper that "there may be additional genetic effects at other loci...". What we were attempting to analyse in our paper, however, were the primary loci responsible for the observed polymorphism. Our model may well be proved incorrect (or incomplete) in the future; I believe however that it is more likely than Galbreath's alternative, and that it stands at present as a valid working hypothesis.

J. E. DOWDING, *79 Monarch Avenue, Glenfield, Auckland 10*

SAP-FEEDING BY THE KAKA (*Nestor meridionalis*) IN SOUTH WESTLAND, NEW ZEALAND

By COLIN F. J. O'DONNELL & PETER J. DILKS

South Island Kakas (*Nestor m. meridionalis*) use two distinct techniques to feed on sap. First they may strip bark from a branch or trunk, exposing the surface cambium, and then lick the sap exudate from the surface. Buller (1888) recorded this behaviour on *Pseudopanax colensoi*, and in South Westland we noted it on *Griselinia littoralis*. Beggs (1988) found that two female Kakas spent 40% of their time in winter feeding in this fashion on mountain beech (*Nothofagus solandri* var. *cliffortioides*). In this note we describe a second, more specialised technique of sap-feeding observed in South Westland.

During our studies of the use by forest birds of tree species, food types and forest strata in South Westland between 1983 and 1985 (O'Donnell & Dilks 1986), we observed South Island Kakas actively "tapping" and feeding on sap from "trapdoors" in the trunks of southern rata (*Metrosideros umbellata*).

Our observations were made during 12-day trips every two months in the Windbag Valley along an altitudinal transect up the Konini Ridge from the valley floor to the bushline at 1100 m a.s.l. At low altitudes the transect passed through forest dominated by rimu (*Dacrydium cupressinum*) and kamahi (*Weinmannia racemosa*). Between 400 and 500 m a.s.l. the forest gradually changed into silver beech (*Nothofagus menziesii*), kamahi, southern rata, and mountain totara (*Podocarpus cunninghamii*), and into pure silver beech above 800 m a.s.l. Most sap-feeding observations were made in forest with a silver beech/southern rata canopy. Kakas have a specialised brush tongue (Garrod 1872, Oliver 1955) with which they can collect liquids such as nectar and sap more effectively than other New Zealand parrots.

SAP-FEEDING BEHAVIOUR

A Kaka would start by peeling and discarding loose bark from the tree trunk. It then used its lower mandible to prise a "trapdoor" through the remaining bark, and gouged a series of tiny holes into the superficial layer of yellow cambium 6-10 mm below the surface. Sometimes, when a bird was hanging upside down, it levered the trapdoor downwards. The resulting horizontal marks on the tree trunk were very distinctive (Figures 1,2, & 3). Marks were obvious on trunks and large branches from ground level to high in the canopy. Almost all trees which had sap-feeding signs had many hundreds of scars (Figure 4).

We watched a bout of sap-feeding for 57 minutes on 7 August 1984 between 1433 and 1530 (NZST). Two Kakas spent an average of 6.6 minutes (range 1-12, n = 7 spells) prising open bark. Between these spells they revisited older scars and extracted sap which had leaked from the wounds. They spent on average 1.8 minutes lapping sap (range 1-3, n = 6 spells). One new scar was visited at least 4 times while we watched the birds.

NOTORNIS 36: 65-71 (1989)

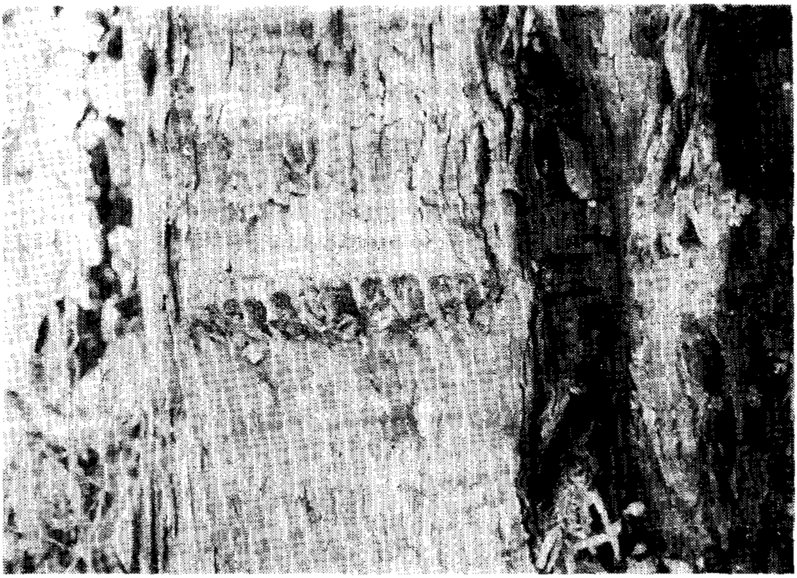


FIGURE 1 — Kaka sap-feeding marks on southern rata. The bark "trapdoors" are levered down to expose the inner cambium layer, which is tapped for sap. (Note the small holes into the cambium.)

FIGURE 2 — Fresh sap-feeding sign on rata with the "trapdoors" levered up at left, and an older row of five holes at right

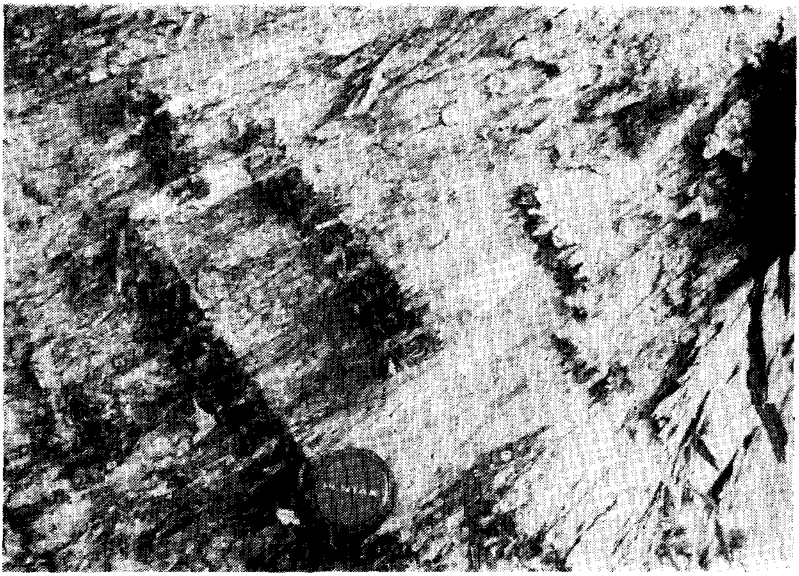


FIGURE 3 — A series of feeding scars on a rata trunk with a lens cap for scale. Two fresh scars at right, three older ones centre and left

FIGURE 4 — *A heavily scarred rata trunk c. 70 cm in diameter. Each scar is formed* by a series of "trapdoors" made during a single bout of sap-feeding

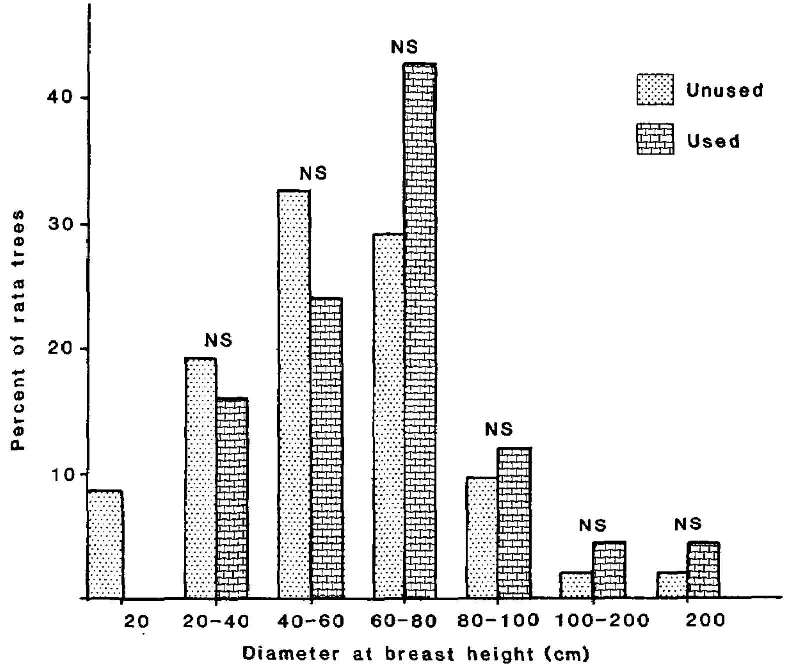


FIGURE 5 — Trunk diameter (dbh) of rata trees used for sap-feeding by Kakas, and of unused trees. The difference between the frequency of use and frequency of availability of rata tree dbh classes was tested using G-test of independence (Sokal & Rohlf 1981) for each size class. NS = no significant differences

PLANT SPECIES USED FOR SAP-FEEDING

Along Konini Ridge we found 37 trees with the characteristic signs of sap-feeding: 26 southern rata, 2 vine rata (*Metrosideros fulgens*), 1 kamahi, 4 rimu and 4 mountain totara. Thus 74% of sign was observed on rata, a species which makes up only 2.6% of canopy tree stems in the Windbag Valley.

We then classed the trunk diameters (dbh) of 74 rata trees, including 26 (35%) which had sap-feeding marks. Although there appears to be a trend towards using larger trees there was no significant difference between rata availability and use (Figure 5). This suggests that the tree diameter and hence the age of a tree did not influence selection by Kakas. Most rata trees selected for sap-feeding had numerous scars of varying ages, some being partly or wholly healed over and others being fresh. All trees with feeding signs looked healthy. Some trees were used repeatedly for sap-feeding whereas others, often close to them, were not visited at all.

SEASONAL AND GEOGRAPHICAL DISTRIBUTION OF SAP-FEEDING

Sap-feeding occurred mainly in late winter and spring, 64% of observations being in August (Table 1). Over the whole year, sap-feeding contributed

TABLE 1 — Seasonal use of sap and nectar by Kakas in South Westland

	USE OF SAP			USE OF NECTAR			
		Proportion of feeding observations	Proportion of sap-feeding observations		Proportion of feeding observations	Proportion of nectar feeding observations	Total number of feeding observations
MONTH	n	(%)	(%)	n	(%)	(%)	(Minutes)
FEBRUARY	0	-	-	118	16.9	30.7	428
APRIL	0	-	-	0	-	-	382
JUNE	0	-	-	23	5.0	6.0	472
AUGUST	57	10.3	64.0	0	-	-	555
OCTOBER	16	3.3	18.0	60	12.4	15.6	485
DECEMBER	16	2.0	18.0	184	22.4	47.7	858
TOTALS	89		100.0	385		100.0	3180

to 2.8% of 3180 minutes of Kaka feeding observations but its importance increased to 10.3% in August when no flower or nectar sources were available (Table 1).

Between 1983 and 1985 about 147 000 ha of forest in South Westland were surveyed (O'Donnell & Dilks 1986). Characteristic sap-feeding marks were recorded throughout these forests from the Copland Valley and Karangarua State Forest in the north, south to Big Bay and inland as far as the Landsborough Valley. Sap-feeding marks were almost always recorded only on rata.

DISCUSSION

We found few references to sap-feeding by New Zealand parrots. Buller (1888) and Beggs (1888) recorded Kaka sap-feeding by the bark stripping technique. McCann (1963) made a statement that the Kakapo (*Strigops habroptilus*) and the Kea (*Nestor notabilis*) feed on sap and gummy exudates from the trunks and branches of trees and shrubs. However, recent detailed studies of both species have not identified sap as forming part of their diets (Jackson 1960, Clarke 1970, Best 1984, O'Donnell & Dilks 1986, R. Powlesland pers. comm.).

It has become clear that Kaka sap-feeding by active tapping occurs widely in other parts of New Zealand. The characteristic marks have been recorded on podocarps, particularly mountain totara, in the central North Island (B. Molloy, pers. comm.), Central Westland (C. Woolmore, pers. comm.), Stewart Island (R. Tindal, pers. comm.) and Codfish Island (R. Nilsson, pers. comm.). Damage to rimu by Kakas in Southland forests reported by Holloway (1948) also appears to be the characteristic feeding sign.

In South Westland, both the frequency of occurrence of sign on trees and the hundreds of scars on each tree indicate that sap-feeding is common. Beggs & Wilson (1987) concluded that Kakas require food with a high net energy return in order to balance their energy budget. Sap could provide this balance when little nectar is available.

Gouging bark specifically to produce a flow of sap is rare among vertebrates, but it has been recorded in primates, marsupials and woodpeckers. Sap is an essential food for the pigmy marmoset (*Cebuella pygmaea*) (Kinzey *et al.* 1975), marmosets of the genus *Callithrix* from Brazil (Coimbra-Filho & Mittermeier 1976), and sapsuckers (*Sphyrapius* spp.) in North America (Rushmore 1969, Ostry & Nichols 1976). The marsupial sugar glider (*Petaurus breviceps*) and yellow-bellied glider (*P. australis*) of Australia specialise in feeding on exudates from *Acacia* and *Eucalyptus* trees (Wakefield 1970, Smith 1982, Craig 1985).

Sap-feeding behaviour in these groups has many parallels with Kaka behaviour. All groups gouge characteristic feeding wounds and return at intervals to feed on the sap. Trees used for feeding by marsupial gliders are no larger than other trees in surrounding forest (Craig 1985). The properties of individual *Eucalyptus* trees which make them suitable as sap sites is not known (Smith 1982). Both yellow-bellied gliders and marmosets have favoured individual trees, sometimes riddled with holes, while other nearby trees of the same species remain untouched (Coimbra-Filho & Mittermeier 1976, Smith & Russell 1982). Like Kakas, gliders feed on sap predominantly in late winter (Smith 1982, Craig 1985).

Sap-feeding in Australia and South Westland occurs mainly on trees of the family Myrtaceae. The sap from these trees may have a high sugar content and corresponding energy value or it may be more voluminous or reliable. Perhaps it is more accessible, rata bark being fibrous and sapwood continuous compared with the hard bark and discontinuous cambium of rimu. Sap-feeding by Kakas is concentrated in late winter and spring, when very few nectar sources are available, temperatures are lower and energy demands are high (Weathers *et al.* 1984). In early spring sap begins rising again and is also probably more accessible (B. Molloy, pers. comm.). The nutritional value of rata sap has not been investigated in New Zealand, but Australian studies have shown that phloem saps of *Eucalyptus* spp. are rich in soluble sugars and low in protein (Stewart *et al.* 1973). Smith (1982) indicated that the exudates produced at two or three feeding sites on a *Eucalyptus* tree would satisfy a glider's daily energy needs. The gum of *Anacardium occidentale* (Anacardiaceae), a principal food of marmosets, is also a high-energy food source containing 84% carbohydrate and several minerals (Coimbra-Filho & Mittermeier 1976).

South Island Kaka weights average about 550 g (Beggs & Wilson 1987), roughly the same as for yellow-bellied gliders (Smith & Russell 1982). Even allowing for differences in energy efficiencies between the species it is likely that quite small amounts of sap may largely satisfy the energy needs of Kakas as they do for gliders. Thus specialisation in the extraction of plant saps could overcome some seasonal shortages of high-energy foods. Sap flow probably increases with rainfall (Smith 1982), making sap a reliable food in Westland, where rainfall ranges between 3000 and 6000 mm per annum.

This sap-feeding behaviour in Kakas raises many questions to investigate. Kakas may have alternative energy sources elsewhere, such as honeydew in the Nelson region (Beggs & Wilson 1987, Beggs 1988) and winter flowering puriri (*Vitex lucens*) and kohekohe (*Dysoxylum spectabile*) in North Island forests. Do Kakas take sap from the eucalypts which occur widely in exotic plantations in the central North Island, or pohutakawa (*M. excelsa*) in coastal areas? Why does almost all sap-feeding occur on ratas in South Westland and why are certain trees preferred? The extensive rata/kamahi dieback in areas of Westland may have a major effect on Kaka distribution and abundance. We found that, in South Westland, Kakas were abundant south of the Paringa River and in low numbers to the north (O'Donnell & Dilks 1986). Paringa River is also the boundary between healthy high-country forest to the south and extensive rata/kamahi dieback to the north. A detailed study of sap-feeding behaviour may be important to the long-term conservation of the Kaka in New Zealand.

ACKNOWLEDGEMENTS

Our thanks to Colin Ogle, Phil Moors, Dave Towns, Jacqueline Beggs and Barrie Heather for critically reading the manuscript.

LITERATURE CITED

BEGGS, J. R. 1988. Energetics of Kaka in a South Island beech forest. Unpubl. MSc thesis, University of Auckland.

BEGGS, J. R.; WILSON, P. R. 1987. Energetics of South Island Kaka (*Nestor meridionalis meridionalis*) feeding on the larvae of kanuka longhorn beetles (*Ochrocydus huttoni*). NZ J. Ecol. 10: 143-147.

BEST, H. A. 1984. The foods of Kakapo on Stewart Island as determined from their feeding sign. NZ J. Ecol. 7: 71-83.

BULLER, W. L. 1888. History of the Birds of New Zealand. 2nd edition.

CLARKE, C. M. H. 1970. Observations on population, movements and food of the Kea (*Nestor notabilis*). Notornis 17: 105-114.

COIMBRA-FILHO, A. F.; MITTERMEIER, R. A. 1976. Exudate-eating and tree-gouging in marmosets. Nature 262:630.

CRAIG, S. A. 1985. Social organisation, reproduction and feeding behaviour of a population of yellow-bellied gliders, *Petaurus australis* (Marsupialia: Petauridae). Aust. Wildl. Res. 12: 1-18.

GARROD, A. J. 1872. Note on the tongue of the Psittacine genus *Nestor*. Proc. Zool. Soc. London 1872: 787-789.

HOLLOWAY, J. 1948. Damage by Kaka in rimu forests of Western Southland. NZ J. For. 5: 437-438.

JACKSON, J. R. 1960. Keas at Arthur's Pass. Notornis 9: 39-58.

KINZEY, W. G.; ROSENBERGER, A. L.; RAMIREZ, M. 1975. Vertical clinging and leaping in a neotropical anthropoid. Nature 255: 327-328.

McCANN, C. 1963. External features of the tongues of New Zealand Psittaciformes. Notornis 10: 326-328, 341-345.

O'DONNELL, C. F. J.; DILKS, P. J. 1986. Forest birds in South Westland. Status, distribution and habitat use. NZ Wildlife Service Occasional Publ. No. 10. (Available from Department of Conservation, Wellington.).

OLIVER, W. R. B. 1955. New Zealand Birds. 2nd ed. Wellington: Reed.

OSTRY, M. E.; NICHOLLS, T. H. 1976. How to identify sapsucker injury on trees. USDA Forest Service Leaflet, Central For. Exp. Stn, St Paul, Minnesota.

RUSHMORE, F. M. 1969. Sapsucker damage varies with trees and seasons. USDA Forest Service Res. Paper NE 136. Upper Darby, Pa.

SMITH, A. P. 1982. Diet and feeding strategies of the marsupial sugar glider in temperate Australia. J. Anim. Ecol. 51: 149-166.

SMITH, A.; RUSSELL, R. 1982. Diet of the yellow-bellied glider *Petaurus australis* (Marsupialia: Petauridae) in North Queensland. Aust. Mammal. 5: 41-45.

SOKAL, R. R.; ROHLF, F. J. 1981. *Biometry*. 2nd ed. New York: Freeman & Co.

STEWART, C. M.; MELVIN, J. F.; DITCHBURNE, N.; THAN, S.M.; ZERDONER, E. 1973. The effect of season of growth on the chemical composition of cambial saps of *Eucalyptus regnans* trees. Oecologia 12: 349-372.

WAKEFIELD, W. W.; BUTTEMER, W. A.; HAYWORTH, A. M.; NAGY, K. A. 1984. An evaluation of time-budget estimates of daily energy expenditure in birds. Auk 10: 459-472.

COLIN F. J. O'DONNELL & PETER J. DILKS, *Science Directorate, Department of Conservation, Private Bag, Christchurch*

SHORT NOTE

Feeding on fruits and flowers by insectivorous forest birds

It has been generally assumed that many species of native forest passerine in New Zealand are entirely insectivorous (Oliver 1955, Falla *et al.* 1979, Reader's Digest 1985). However, some reputedly insectivorous forest passerines have occasionally been seen feeding on fruit or from flowers (Riney *et al.* 1959, St Paul 1976, Willoughby 1976, Henderson 1977, Child 1978, Gill 1980, Powlesland 1981, Moeed & Fitzgerald 1982, Wardle 1984, Elliott & Ogle 1985). The death of some "insectivorous" birds during 1080 poisoning operations is also an item of evidence for common feeding on vegetable matter, although it has not been certain whether birds ate baits or poisoned insects (Harrison 1978, Spurr 1979). No-one has tried to find out how widespread or significant is this use of fruits and flowers.

While investigating habitat use by forest birds in South Westland, we recorded the foods of 25 forest bird species. We found that six "insectivorous" passerines – (Rifleman (*Acanthisitta chloris*), Brown Creeper (*Finschia novaeseelandiae*), Yellowhead (*Mohoua ochrocephala*), Grey Warbler (*Gerygone igata*), Fantail (*Rhipidura fuliginosa*), and Yellow-breasted Tit (*Petroica macrocephala macrocephala*) – occasionally fed on fruit and from flowers.

METHODS

We made 24 405 feeding observations on the six "insectivorous" species in the Windbag Valley, South Westland. We recorded the use of plants and food types by instantaneous sampling along line transects in the valley (O'Donnell & Dilks 1986). The transects were walked daily for 10 days every 2 months between October 1983 and December 1985, usually by four observers.

A full description of the Windbag Valley is in O'Donnell & Dilks (1986). This inland montane valley is dominated by mixed podocarp-hardwood and beech forests comprising mainly rimu (*Dacrydium cupressinum)*, kahikatea (*D. dacrydioides*), mountain totara (*Podocarpus cunninghamii*), miro (*Prumnopitys ferruginea*), kamahi (*Weinmannia racemosa*), southern rata (*Metrosideros umbellata*), and silver beech (*Nothofagus menziesii*).

RESULTS

Feeding from flowers

Only three species were observed feeding from flowers. These observations represented less than 1% of the total feeding observations for each species. We recorded Brown Creeper gleaning from *Pseudopanax simplex* flowers on only one occasion (0.04% of 2353 feeding observations). We recorded Yellowheads at mistletoe (*Peraxilla colensoi*) flowers on six occasions (0.8% of 712 observations). On each occasion the birds visited many flowers, foraging within their long tubular tepals. Single records of Fantails feeding from *Fuchsia excorticata* and *Coprosma rotundifolia* represented 0.04% of 5161 feeding observations. The Brown Creeper and Yellowhead observations were made in February and the Fantail records in October. We could not tell what the birds were actually eating from the flowers. They could have been taking invertebrates or nectar.

TABLE 1 — Plants used as fruit sources by insectivorous passerines in South Westland

	Altitude	Rifleman	Brown Creeper	Yellowhead	Grey Warbler	Fantail	Yellow-breasted Tit	Observations n	Observations %
Trees									
Dacrydium cupressinum	L	-	-	-	1	-	1	2	2.5
D. dacrydiodes	L	-	2	-	-	-	-	2	2.5
Weinmannia racemosa	L	-	-	-	1	-	1	2	2.5
Shrubs									
Ascarina lucida	L	-	-	-	-	8	7	15	18.5
Coprosma astoni	H	-	1	-	-	-	-	1	1.2
C. pseudocuneata	H	-	-	-	-	-	1	1	1.2
C. foetidissima	H	-	-	-	-	1	-	1	1.2
Fuchsia excorticata	L	-	-	-	-	2	-	2	2.5
Griselinia littoralis	H	-	-	3	1	-	-	4	4.9
Pseudopanax crassifolius	H	-	5	-	-	-	10	15	18.5
P. edgerleyi	H	8	-	-	8	2	1	19	23.5
P. simplex	H	6	4	-	6	-	1	17	21.0
Total		14	12	3	17	13	22	81	100.0
No. of feeding obs. for each bird sp.		2073	2353	712	6997	5161	7109		
% feeding on fruit		0.7	0.5	0.4	0.2	0.3	0.3		

L = Characteristic of lower altitudes (<500 m) in the Windbag Valley
H = Characteristic of higher altitudes (>500 m) in the Windbag Valley

Feeding on fruit

Single birds and small groups from all six species ate fruit, but these items represented less than 1% of the diet of the six species over the year (Table 1). However, both Rifleman feeding on *Pseudopanax* and Tit and Fantail on *Ascarina* consumed dozens of fruits during each observation. Both plants have large clusters of fleshy fruits, usually less than 5 mm in diameter. Birds ate green as well as ripe fruits.

Three species of canopy plant (7.5% of observations) and eight of understorey plant (92.5%) were used. The most favoured plant was *Pseudopanax* with 63% of the fruit-feeding observations coming from three species in this genus (Table 1). Most observations (72%) were of birds using plants characteristic of higher altitudes (>500 m a.s.l.). Only the Tit and the Fantail used lowland plants to any extent. Most fruit eating occurred in autumn and winter (Table 2), just over 70% of observations being made in June and August.

TABLE 2 — Seasonal occurrence of fruit feeding by insectivorous passerines in South Westland

	Rifleman	Brown Creeper	Yellowhead	Grey Warbler	Fantail	Yellow-breasted Tit	TOTAL	
							n	%
February	-	-	3	2	3	-	8	9.9
April	4	-	-	1	-	2	7	8.6
June	10	4	-	8	9	11	42	51.9
August	-	3	-	2	1	9	15	18.5
October	-	5	-	4	-	-	9	11.1
December	-	-	-	-	-	-	0	-

DISCUSSION

There may be no obligate insectivorous passerines native to New Zealands forests. Nevertheless, the six species discussed in this note are still accurately described as insectivores because their fruit and flower feeding represented such a small proportion of their total diets. As most of the fruit eating occurred on plants characteristic of higher altitudes during autumn and winter, insectivores may feed on fruit when invertebrates are scarce and the weather is harsher. Moeed & Fitzgerald (1982) recorded fruits and seeds in the faeces of Fantail, Pied Tit, Rifleman and Whitehead *(Mohoua albicilla)*, mainly in autumn and winter. They suggested that fruit may make an important contribution to the birds' energy budgets. More vegetable food may be eaten when not enough animal food is available (Powlesland 1981), and in South Westland invertebrate numbers in winter are 6-7 times lower than in summer (Robertson *et al.* 1986). Even the brief bouts of intensive fruit eating, such as we saw with Rifleman, could be important in maintaining the birds' daily energy in winter.

All native insectivorous forest passerines have now been recorded eating fruit, and from a wide variety of plant genera (21 genera, Table 3). However, given the low proportions in their diet, these species are not likely to be important seed dispersers, in contrast to some other New Zealand forest birds (Clout 1982, Norton 1982).

Feeding from flowers is negligible among the few insectivorous species for which it has been recorded. These birds may actually be feeding on small invertebrates in the flower, as Elliott & Ogle (1985) suggested for Yellowheads.

TABLE 3 — Plant genera recorded as fruit and flower sources for insectivorous forest passerines in New Zealand

Plant Genera	Rifleman	Brown Creeper	Yellowhead	Whitehead	Grey Warbler	Fantail	Yellow-breasted Tit	Robin
Ascarina						*	*	
Astelia			*					*
Dacrydium	*	*		*	*	*	*	
Carpodetus				*				*
Coprosma		*				*	*	*
Coriaria								*
Corokia								*
Cyathodes				*			*	*
Fuchsia				*		*		
Freycinetia				*				
Geniostoma				*			*	
Griselinia			*	*	*		*	
Melicytus				*				*
Muehlenbeckia								*
Myrsine				*				
Pittosporum				*				*
Peraxilla			*					
Pseudopanax	*	*		*	*	*	*	*
Pseudowintera			*					
Rubus								*
Weinmannia					*		*	

Sources: this study, Riney *et al.* 1959, St Paul 1976, Willoughby 1976, Henderson 1977, Child 1978, Gill 1980, Powlesland 1981, Moeed & Fitzgerald 1982, Wardle 1984, Elliott & Ogle 1985

ACKNOWLEDGEMENTS

These observations were made while we were staff of the New Zealand Wildlife Service, which was incorporated into the Department of Conservation in April 1987. We thank Locky Carmichael, Dave Crow, Erica Law, Peter McClelland, Peter Notman, Paul Pearson, Noel Phillips, Andrew Read, Andrew Roberts, Noel Ward and Jackie Whitford for helping collect data; and Phil Moors, Mick Clout, Richard Sadleir and John Innes for commenting on the manuscript.

LITERATURE CITED

CHILD, P. 1978. Yellowhead not entirely insectivorous. Notornis 25: 252-253.

CLOUT, M. N. 1982. Seed-dispersing birds in New Zealand. Notornis 29: 338.

ELLIOTT, G. P.; OGLE, C. C. 1985. Wildlife and wildlife habitat values of Waitutu Forest, Western Southland. *Fauna Survey Unit report* No. 39. NZ Wildlife Service (Available from Department of Conservation, Wellington).

FALLA, R. A.; SIBSON, R. B.; TURBOTT, E. G. 1979. The New Guide to the Birds of New Zealand. Auckland: Collins.

GILL, B. J. 1980. Abundance, feeding, and morphology of passerine birds at Kowhai Bush, Kaikoura, New Zealand. NZ J. Zool. 7: 235-246.

HARRISON, M. 1978. The use of poisons and their effect on birdlife. Pages 203-221 *In* Proceedings of the seminar on the Takahe and its habitat 1978. Fiordland National Park Board, Invercargill.

HENDERSON, N. M. 1977. Autumn and winter flocking behaviour of the Brown Creeper *(Finschia novaeseelandiae).* Mauri Ora 5: 75-88.

MOEED, A.; FITZGERALD, B. M. 1982. Foods of insectivorous birds in the forest of the Orongorongo Valley, Wellington, New Zealand. NZ J. Zool. 9: 391-402.

NORTON, S. A. 1982. Bird dispersal of *Pseudowintera* seed. Notornis 29: 91-92.

O'DONNELL, C. F. J.; DILKS, P. J. 1986. Forest birds in South Westland. Status, distribution and habitat use. NZ Wildlife Service Occasional Publication No. 10. (Available from Department of Conservation, Wellington).

OLIVER, W. R. B. 1955. New Zealand Birds. 2nd ed. Wellington: Reed.

POWLESLAND, R. G. 1981. The foraging behaviour of the South Island Robin. Notornis 28: 89-102.

READER'S DIGEST. 1985. Reader's Digest Complete Book of New Zealand Birds. Sydney: Reader's Digest.

RINEY, T.; WASTON, J. S.; BASSET, C.; TURBOTT, E. G.; HOWARD, W. E. 1959. Lake Monk expedition. An ecological study in Southern Fiordland. DSIR Bull. 135, Wellington.

ROBERTSON, H. R.; *et al.* 1986. Ecology of Seral Kahikatea forest in South Westland. Ecology Division report, DSIR. 100 p.p.

St PAUL, R. 1976. A bushman's seventeen years of noting birds. Part C – North Island Rifleman, Whitehead, Pied Tit and North Island Robin. Notornis 23: 220-232.

SPURR, E. B. 1979. A theoretical assessment of the ability of bird species to recover from an imposed reduction in numbers, with particular reference to 1080 poisoning. NZ J. Ecol. 2: 46-63.

WARDLE, J. A. 1984. The New Zealand beeches. Ecology, utilisation and management. NZ Forest Service, Christchurch.

WILLOUGHBY, H. B. G. 1976. Bird recolonisation of regenerated beech *(Nothofagus)* forest. Unpubl. Dip. Wild. Management Dissertation, University of Otago, Dunedin.

COLIN F. J. O'DONNELL and PETER J. DILKS, *Science Directorate, Department of Conservation, Private Bag, Christchurch*

★

Establishment of the Black-fronted Dotterel in Southland

Colonisation in Southland by Black-fronted Dotterels *(Charadrius melanops)* began in the lower reaches of the Aparima River and in the Te Anau area in or before 1980 and in the lower reaches of the Oreti River in 1985. The status of the species on the Mataura River is unknown but one pair was seen on the lower reaches in 1982 and 1985. On the Aparima River by 1985, 24 birds, mostly in pairs, were widely distributed between Gummies Bush near the coast and Wrey's Bush 50 km inland. Small winter flocks have occurred inland on the rivers.

Patterns of establishment in New Zealand by the Black-fronted Dotterel have been described by N. B. Mackenzie for Hawke's Bay, B. D. Heather for Wairarapa and P. & M. Child for Central Otago. In Southland all but two of the early records from 1962 to 1980 were coastal sightings of birds in ones and twos. Breeding was first suspected in 1980 on the Aparima River, and in the same year two birds were reported from the lower Mararoa River in the Te Anau area. By 1985 the species had established itself on those waterways and was breeding also on the lower Oreti River and probably the lower Mataura River. This account summarises the status of the species in Southland.

LOCALITY SUMMARIES

Aparima River: First recorded at Thornbury 13.1.80, 3 birds, probably then breeding. Two nests found 26.10.81. On monthly checks of this site between February 1982 and December 1983, Owen Linscott found 2 birds on most visits until August 1983 but none September to December. Two were there again, displaying, in October 1985. In 1985 the species was breeding on the lower and middle reaches, between Gummies Bush and Wrey's Bush, approximately 50 km upstream. In November 1986 a pair nested on a road verge 200 m from the riverbed and separated from it by willows, pasture, a country rubbish tip and the road. On 25.3.88 1 bird and 27.4.88 2 birds were found on the contributory Otautau Stream.

Numbers: 24 birds (7 pairs, 10 singles) and 3 nests were found on an OSNZ survey of the riverbed from source to coast on 22/26.10.85. Behaviour of all pairs and some single birds indicated that more than three pairs were breeding. Twenty adults and 1 chick were found between Wrey's Bush and Thornbury by an OSNZ party in January 1987 during a national field study week. On 5.3.88 a flock of 10-12 were moving to and fro over a distance of about 600 m upstream and downstream of the Otautau bridge. They were still there on 12.3.88.

Oreti River: None found on an OSNZ survey of the whole river in October 1974. First sightings at Branxholme on lower reach, October-November 1985, 2 birds, breeding suspected. OSNZ river survey October 1986 found 4 adults and 1 juvenile between Branxholme and Riverton Road bridge but none further upstream.

Mataura River: 1 at Mataura Island 20.12.77 and 2 at Wyndham 25.2.82 and 28.4.85 indicate a presence on the lower reaches. Status unknown but breeding probable. There is some apparently suitable habitat. The river has not been surveyed by practised observers of the species.

Te Anau area

Lower Mararoa River: 2 at Riverslea 4.5.80; 6 at mouth 3.8.80. On 3.4.85 none were found between Key bridge and Whitestone mouth, but 4, including 1 immature, were seen between Whitestone and Mararoa dam. 13.10.85, 3 at Mararoa mouth; 2.11.85, 5 single birds (1 false brooding) between Whitestone mouth and Mararoa mouth; 3.11.85, 2 copulating, another false brooding; 27.11.85, 1 adult and 1 juvenile; 22.12.85, 1 adult.

Winter counts: Mararoa dam, 9 on 22 and 26.5.85; 7 on 16.6.85, 5 on 29.6.86. Mararoa mouth, 9 on 23.5.87.

Lower Whitestone River: 1 on 6.3.82, 2 on 15.9.84, 0 on 7.10.84, 1 on 17.9.85 and 2.11.85, 2 (1 at mouth, 1 at 1.2 km upstream) on 3.11.85, 1 on 5.9.87.

Most Te Anau area sightings were made by Kim and Jenny Morrison who say: "Black-fronted Dotterels have been resident on the Mararoa River since at least 1980 and breeding has been probable . . . . Birds might have been colonising the lower Whitestone River since 1984 though suitable habitat is limited. We have not seen Black-fronted Dotterels on the Eglinton River, Upukurora River or upper Whitestone River although there are suitable places for them".

Other: Records from Waimatuku Mouth are: 1 in January 1962; 2 on 2.6.66; 1 on 6.6.70; 2 on 28.6.70; 2 on 29.4.72; 1 on 29.4.85. The samolus flats and sandhills of Waimatuku Mouth are not breeding habitat for the species. Single birds seen at Riverton in 1963, Makarewa River near Wallacetown in January 1973, Waituna Lagoon on 28.11.77 and Lake George in February 1983.

Post-breeding movement: Autumn and winter sightings of birds in ones and twos on wetlands near the coast indicate post-breeding movement away from the breeding grounds by some birds. Three reports of small inland flocks were of 9, 7 and 6 on the Mararoa in May, June and August and 10-12 on the Aparima in March.

DISCUSSION

Aparima River records give evidence of initial breeding on the lower reaches and extension within five years to about 50 km upstream. In that time numbers apparently increased from 1 - 2 pairs to 7 - 12 pairs. Earlier presence upstream than appears in the records cannot be discounted but is unlikely. The Aparima is a popular fishing river and is fished by several Southland OSNZ members. They and Southland Acclimatisation Society field officers are not likely to have left Black-fronted Dotterels unremarked or unreported.

Initial breeding on the Oreti River (proven) and Mataura River (probable) has, as on the Aparima, been on the lower reaches. This initial establishment, when considered together with the post-breeding move to the coast by some birds, and the early records from the coast, suggests that early colonisers in Southland may have arrived by the coastal route. Alternatively, Barrie Heather (pers. comm.) suggests that it may merely be that the greatest choice of feeding habitat is in the lower reaches, and that the same (lower reach initial establishment) is true of the Wairau and Awatere Rivers in Marlborough and the Mohaka River in northern Hawke's Bay.

The roadside nest in 1986 raises the question of population pressure, and whether, even at that apparently early stage of colonisation, optimum numbers had been reached on the Aparima riverbed. I have walked most of this riverbed several times since 1985 while collecting data on Banded Dotterel *(C. bicinctus)*. Despite changing water levels and channel variations, each year there were sections of apparently suitable habitat (raised mixed-grade shingle terrace handy to quiet shallow water and some damp mud or silt) which did not hold Black-fronted Dotterels. Barrie Heather (pers. comm.) knows of North Island nests outside the riverbeds. He sites an early record from Dave Sim of a Wairarapa pair nesting on the shingle berm of a road close to the lower Ruamahanga River, and regular breeding in the shingle and mud bottoms of gravel borrow-pits within Masteron Borough boundary and elsewhere. The roadside nest near the Aparima, and the North Island records, indicate that any river survey which is limited to the riverbed and its berms may be inadequate when looking for this species.

ACKNOWLEDGEMENTS

This account is based on reports from M. L. Barlow, R. Boud, J. Hall-Jones, O. J. Linscott, B. D. Heather, I. A. Mathieson, J. V. and K. Morrison, P. M. Muller, L. J. Richards, H. A. Robertson, S. A. Smithies, S. Sutherland, M. R. Sutton and R.R. Sutton. Many Southland OSNZ members have walked and waded long sections of the Aparima, Oreti and Mararoa Rivers in search of the species, mostly without success. I thank Barrie Heather for his comments on the manuscript.

LITERATURE CITED

CHILD, P. 1982. A new breeding species for Central Otago: Black-fronted Dotterel. Notornis 29:99-100.

CHILD, P. & M. 1984. The Alexandra Black-fronted Dotterels: 1982/83 season. Notornis 31: 31-39.

HEATHER, B. D. 1973. The Black-fronted Dotterel *(Charadrius melanops)* in the Wairarapa. Notornis 20: 251-261.

MACKENZIE, N. B. 1962. A new breeding bird for New Zealand: Black-fronted Dotterels in Hawke's Bay. Notornis 9: 269-270.

MACKENZIE, N. B. 1963. The Black-fronted Dotterel in Hawke's Bay. Notornis 10: 202-206.

MAIDA BARLOW, *38 Filleul Street, Invercargill*

REVIEW

New Zealand Birds: a Sound Guide; volume 1. North Island Brown Kiwi to Blue Petrel

This cassette is the first in a series which aims to present recordings of all the species and subspecies of birds on the New Zealand checklist. This daunting task has been undertaken by Les McPherson, who has himself recorded much of the material to be used over the past 20 years. Other recordings were commissioned and the balance obtained from a wide variety of sources (both local and overseas) by donation or exchange. Volume 2 should be available by the end of 1988 and it is hoped to have the series of four or five cassettes completed in time for the IOC in 1990.

Volume 1 covers 59 species or subspecies, with recordings dating from 1955 to 1986. Side 1 deals with the kiwis, penguins, grebes, albatrosses and some mollymawks; side 2 contains the rest of the mollymawks, fulmars and the gadfly petrels. The average track length is a little under 1 minute, but there is considerable variation, with the shortest at 10 seconds (North Island Brown Kiwi) and the longest at 2 minutes 17 seconds (Snares Cape Pigeon). The overall quality of these recordings is very high, especially when it is considered that most of them had to be obtained in the windy and inhospitable conditions which normally prevail on subantarctic islands and in Antarctica itself.

Obviously, limits must be imposed on the length of each recording in a production such as this, and nearly all the selections are well judged. The only real disappointment for me was the recording of the North Island Brown Kiwi – less than 10 seconds of call and from a male only. Considering that this could be one of most useful calls in the present volume, it is a shame that a slightly longer recording featuring both sexes was not included. On the other hand, many of the selections are a surprise and a delight; no doubt each listener will have his or her own favourites, but I find it hard to go past the strange, other-worldly but beautiful trumpeting of the Emperor and King Penguins.

Each recording is introduced on the tape by its common name. The two voices used (one male and one female) are clear and there are no irritating gaps between selections. The handbook which accompanies the tape is clear, is easy to use and has all the information that most listeners could need. Each listing shows the scientific and common names of the species or subspecies and a brief note on the subject, e.g. "Calls of adult at nest, with chicks in background". This is followed by the location, date (and in some cases time of day) of the recording, its duration and the name of the recordist. The only faults I can find with the handbook are trivial - in one instance *Eudyptula* is misspelt and in a few cases recent changes in taxonomy have altered scientific names.

In his written introduction Mr McPherson notes that "It is inevitable in a production of this kind that there will be some omissions". The only ones that I can find are the NZ Dabchick (a rather silent species at the best of times) and seven of the rarer *Pterodroma* species *(solandri, alba, magentae,* *longirostris, pycrofti, leucoptera* and *axillaris),* some of which may never have been recorded. Aside from these, coverage is complete and thus includes the highly unlikely and the exotic – recordings of Moseley's Rockhopper Penguin, Magellanic Penguin and Black-footed Albatross all testify to the compiler's industry and perseverance. Ultimately it is hoped to produce a supplementary tape at the end of the series to accommodate as many of the omissions as possible; anyone who may be able to fill any of the gaps is welcome to write to the address below.

Mr McPherson is to be congratulated on his enterprise; when this series is complete it will form an outstanding and unique record of the calls and songs of New Zealand's birds. It deserves to be available in every library and should be in the collection of all those with a serious interest in our avifauna. The present volume brings us a wonderful collection of sounds, many of which most of us will never have the chance to hear in the wild. Later cassettes, particularly those dealing with land and shore birds, will have obvious applications in the fields of education and bird identification. In addition, the whole series will be an indispensable aid to the growing number of foreign birdwatchers visiting New Zealand.

Volume 1 is available from McPherson Natural History Unit, P.O. Box 21083, Edgeware, Christchurch, New Zealand, for NZ$15.00 post paid.

John Dowding