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Journal of the Ornithological Society
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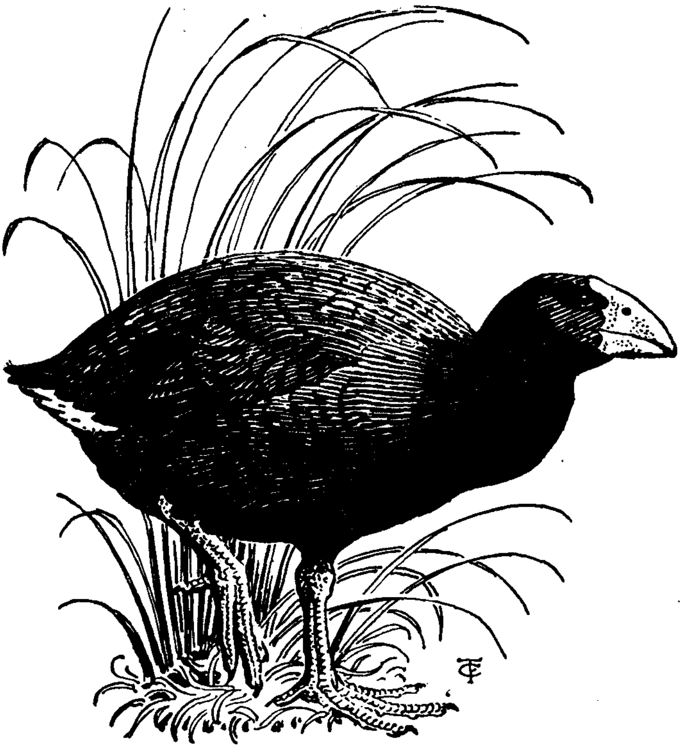

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FEEDING BEHAVIOUR AND OTHER NOTES ON 20 SPECIES OF PROCELLARIIFORMES AT SEA

By PETER C. HARPER

ABSTRACT

Between January 1965 and March 1967 4926 observations were made on 20 species of petrel feeding in the Southern Ocean from the research ship USNS *Eltanin*. Most observations were made at night while the ship was stopped on oceanographic research stations. Observations were made possible by bright decklights, following birds with the powerful bridge lights, or under moonlight. Eleven feeding methods were distinguished. Most common were surface seizing (49.1%: used by 14 species), dipping (25.2%: 9 species), and surface plunging (c.6%: 6 species). Seven species foraged entirely at night, and five fed by day only. Food recorded was chiefly crustaceans and squid. The submergence time and prey-handling time for some species are also given.

INTRODUCTION

In the late 1960s and early 1970s the main trend of interest in seabirds was to identify seabirds, rather than to inquire what the birds were doing at sea. Times have changed. The last decade has seen a great interest in seabird diet and feeding methods (e.g. Ainley 1977, Croxall & Prince 1980, Prince 1980 a, b, Brown *et al.* 1981, Clark *et al.* 1981, Imber 1981, Morgan & Ritz 1982, Hunter 1983, Croxall *et al.* 1984, Green 1986).

In a recent review, however, Croxall (1984) emphasised how few observations there are of Procellariiformes feeding, particularly under natural conditions, and especially to support the substantial circumstantial arguments that they do so extensively at night. Moreover, his statement that most petrels "probably catch their prey by 'surface seizing' is a brief but rather accurate summary of what is known on how petrels catch their food.

The purpose of this paper is to provide details of observations deriving from eight *Eltanin* cruises in the Southern Ocean between 1965 and 1967, and in particular:

1. To show that Procellariiformes can feed effectively at night both under natural conditions and on prey attracted to ships by lights;
2. To show that Procellariiformes can catch live squid, sometimes of considerable size;
3. To show the extent to which some species of Procellariiformes forage either by night or by day; and
4. To provide information on topics such as submergence time and prey handling time, rarely recorded for seabirds at sea.

METHODS

Figure 1 shows where *Eltanin* cruised and the dates for each of the eight cruises while I was aboard. During the 363 day, 30 000 nautical mile journey, the Polar Front (Antarctic Convergence) was crossed 15 times. My main preoccupations at the time were to study prions (Harper 1972, 1980) and to gather information for an identification guide to the southern albatrosses and petrels (Harper & Kinsky 1978). My notes on the feeding behaviour of petrels were recorded incidentally.

While *Eltanin* cruised at 9 knots between oceanographic stations, I made bird observations for most of the day from either the bridge or the helicopter deck some 15 m above the waterline. Birds were counted and observed within a 180° field of view in front of and behind the ship, providing a census strip about 0.8 km in width. In calm weather the bow and stern were good points from which to watch birds closely. I used 7x50 binoculars. The ship's position was plotted by satellite navigation. Air and sea surface temperature (SST), sea state, wind speed and direction, and ocean depth were all plotted hourly and were available in the form of data sheets. All times given below are local.

The *Eltanin* frequently stopped for up to 30 h for oceanographic research. During this time, the ship was brilliantly lit up and various forms of plankton, including crustaceans, were attracted to her beacon-like decklights. On calm clear nights squid could be both seen and heard splashing and darting about after their prey. This activity also occurred when the ship was in darkness, and is presumably due to the well-known diurnal vertical migration of zooplankton to the sea's surface at night.

I sometimes had excellent views of squid in the water and occasionally caught one on an unbaited line hung over the side of the ship. My attempts to catch them with a fine-meshed net were mostly unsuccessful. The krill sometimes proved a problem for the ship stopped on station, in that they blocked the three-foot square seawater intakes to the engines. In the Scotia Sea (Cruise 22) a bucketful of Antarctic krill, *Euphausia superba*, was extracted about every 10 hours after dark, with a smaller amount taken during daylight hours. In this way, the presence of crustaceans in the water was confirmed and the species identified. I measured straightened euphausiids from the tip of the rostrum to the caudal end of the telson with vernier calipers.

Seabirds frequently fed at night about the ship. Many came to the decklights and set about feasting in the water; others were spot-lit, while feeding, with 1500 W bridge signalling lights. The powerful signalling lights (effective operating range of 4 km) had slatted blinkers so that they could be swung in complete darkness over a wide arc and easily opened at will on the unsuspecting birds. They were invaluable not only in confirming that petrels were feeding beyond the range of the decklights, but also in attracting birds on board in times of poor visibility when the birds were easily blinded (Harper 1972).

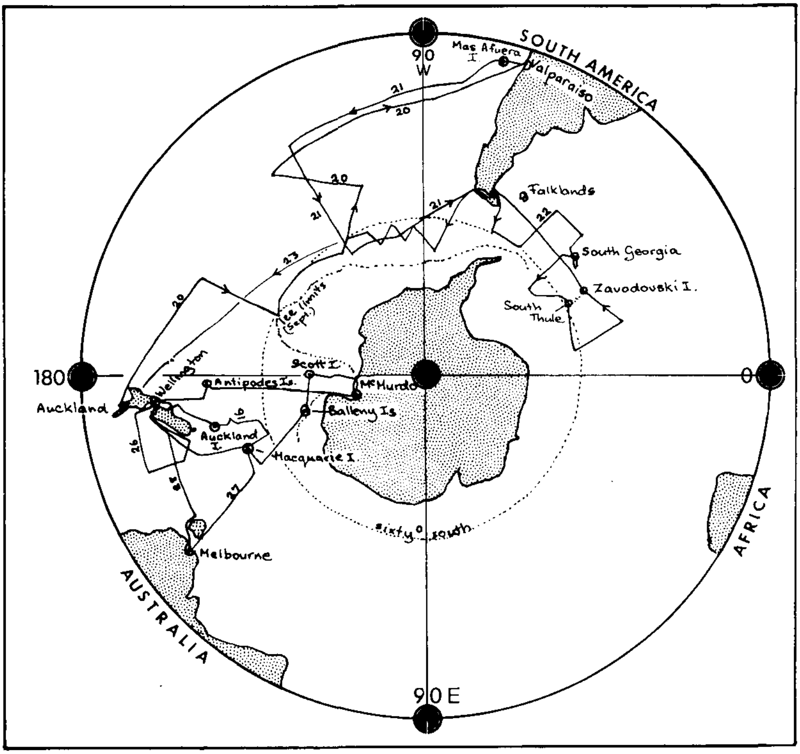

FIGURE 1 — Cruise tracks of Antarctic research ship USNS *Eltanin* 1965-1967

ITINERARY

Cruise 16	28 Jan - 26 Feb 1965	NZ Subantarctic
Cruise 20	14 Sep - 12 Nov 1965	NZ-South Pacific-Chile
Cruise 21	23 Nov - 8 Jan 1966	Eastern Pacific
Cruise 22	19 Jan - 17 Mar 1966	South Atlantic
Cruise 23	31 Mar - 30 May 1966	Chile-South Pacific-NZ
Cruise 26	29 Nov - 20 Dec 1966	Tasman Sea
Cruise 27	31 Dec - 1 Mar 1967	NZ-Ross Sea-Australia
Cruise 28	10 Mar - 28 Mar 1967	Tasman Sea

From the deck about 3 m above the sea, I could observe the feeding petrels, some of which were species rarely seen close to the ship by day (e.g. *Pterodroma* petrels). I could watch them very closely; e.g. I could see them shut their eyes while they fought larger squid. I did not see any birds catching fish, however, although the trawl catches (0-300 m) indicated that fish were certainly present during some of the observations.

What follows is an annotated species list of the petrels I saw feeding from the *Eltanin*, together with a few general behavioural notes made on other occasions. The species listing mainly follows the New Zealand Checklist (Kinsky *et al.* 1970). For each species the foraging techniques, defined below, are in descending frequency of occurrence; 'prey handling time' is defined as the time spent capturing and disposing of prey; these sequences were sometimes timed with a stopwatch. Each observation is of one bird feeding in a particular way. Whenever birds were all foraging in the same way, I have counted them and totalled the number of observations. This procedure took time, and therefore my total counts are conservative. If birds in a large flock were all feeding concurrently, I estimated their numbers. These are noted as n = c.1000.

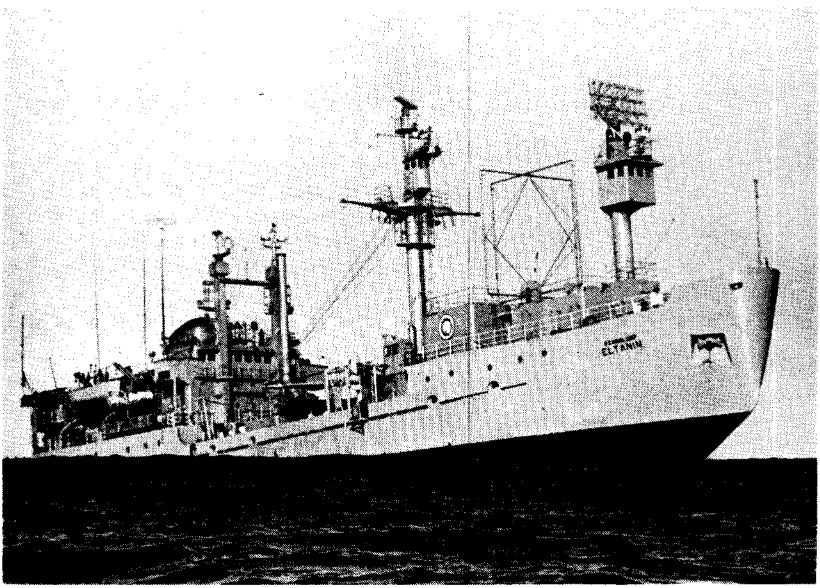

FIGURE 2 — USNS *Eltanin* at sea, riding over a low 3 m swell

DEFINITIONS

The definitions below are derived from a recent review and redefinition of seabird feeding methods (Harper *et al.* 1985).

Surface feeding: A bird remains on the surface while taking food.

Surface seizing: A bird grasps individual prey items with its bill.

Surface filtering: A bird filters out and swallows many food items at a time from the water.
Hydroplaning: A bird filters minute plankton with its breast on the water surface, its head immersed and its wings outstretched, propelling itself through the water with its feet.

Flight feeding: A bird remains airborne, capturing prey at the water's surface; it may momentarily cease flying, but it makes little or no contact with the water.
Dipping: A bird in flight picks prey from on or just below the surface of the sea with little or no use of its feet. Only the bill, head or breast makes momentary contact with the water.
Pattering: A bird uses its feet as well as its wings to maintain a precise height above the water and feeds by picking minute prey items from the surface.

Plunging: A bird in flight plunges into the water, using the momentum of the fall to help it catch prey without pursuit swimming.
Surface plunging: A bird splashes into the water without fully submerging.
Shallow plunging: A bird submerges completely but penetrates little more than its own body length below the water surface.
Deep plunging: A bird submerges completely and penetrates several metres under water, usually preceded by a high near-vertical dive.

Diving: A bird settled on the water surface submerges completely to catch its prey.
Pursuit diving: A bird that is settled on the water dives and pursues its prey underwater by pursuit swimming, using its wings or its feet.
Surface diving: A bird submerges only momentarily, directly on to prey with little or no pursuit swimming.

Pursuit plunging: A bird in flight plunges into the water and then pursues prey underwater by pursuit swimming, using its wings or feet for propulsion.

RESULTS

In all, 4926 observations were made on petrels representing 20 species of seven genera (Table 1). The feeding behaviours, expressed as a percentage of the total observations, are shown in Table 2. Table 3 shows the percentage of records for each species for individuals feeding by day and by night. Specimens of birds collected during the *Eltanin* cruises are in the National Museum, Wellington.

ALBATROSSES AND MOLLYMAWKS

WANDERING ALBATROSS *Diomedea exulans*
ROYAL ALBATROSS *D. epomophora*

Wandering Albatrosses commonly followed the *Eltanin*, and sometimes particular birds which could be individually identified followed us for several days. Adult male and female birds in the South Pacific were seen displaying to each other in the water (facing each other with wings extended and sky pointing with the bill). On one occasion a male and female attacked an immature bird which approached, putting it to flight (18 Dec 65: 49°02′ S

TABLE 1 — Summary of observations made on petrel feeding behaviour during eight voyages of USNS *Eltanin* 1965-1967. For definitions of behaviour, see text.

SPECIES	DIVING		PLUNGING			SURFACE FEEDING				FLIGHT FEEDING		
	Pursuit dive	Surface dive	Surface plunge	Shallow plunge	Deep plunge	Surface seize	Ice gleaning	Surface filter	Hydro-plane	Dipping	Pattering	Total obs
Wandering Albatross		3		2		256						261
Black-browed Mollymawk	1		4			227						232
Light-mantled Sooty Albatross			2			21		4				27
Giant Petrels(both species)		8	7			193		19				227
Cape Pigeon	21	33	77			169		44	2	58		404
Snow Petrel						54	19			141		214
Grey-faced Petrel						27				22		49
Kerguelen Petrel										40		40
Mottled Petrel						4				10		14
Juan Fernandez Petrel						1						1
Broad-billed Prion			c200			22		14	251			c.487
Antarctic Prion		21				402		5	96	c.41		c.565
Thin-billed Prion						131				77	98	306
Fairy Prion			4			901				756	48	1709
Grey Petrel					13							13
White-chinned Petrel					2	11						13
Short-tailed Shearwater	26				33							59
Black-bellied Storm Petrel										21		21
Wilson's Storm Petrel										77	207	284
TOTAL OBSERVATIONS	48	65	c.294	2	48	2419	19	86	349	c.1243	353	c.4926

TABLE 2 — Feeding behaviours expressed as a percentage of the total number of observations made from USNS *Eltanin* 1965-1967.

SPECIES	Pursuit dive	Surface dive	Surface plunge	Shallow plunge	Deep plunge	Surface seize	Ice gleaning	Surface filter	Hydro-plane	Dipping	Pattering	Total obs
Wandering Albatross		1		1		98						261
Black-browed Mollymawk	1		1			98						232
Light-mantled Sooty Albatross			7			78		15				27
Giant Petrels(both species)		4	3			85		8				227
Cape Pigeon	5	8	19			42		11	1	14		404
Snow Petrel						25	9			66		214
Grey-faced Petrel						55				45		49
Kerguelen Petrel										100		40
Mottled Petrel						29				71		14
Juan Fernandez Petrel						100						1
Broad-billed Prion			c.40			5		3	52			c.487
Antarctic Prion		4				71		1	17			c.565
Thin-billed Prion						43				25	32	306
Fairy Prion			1			53				44	3	1709
Grey Petrel					100							13
White-chinned Petrel					15	85						13
Short-tailed Shearwater	44				56							59
Black-bellied Storm Petrel										100		21
Wilson's Storm Petrel										27	73	284
												c.4926

TABLE 3 — Percentage records for each species for individuals feeding by day and by night

SPECIES	Day feeding %	Night feeding %	Total obs
Wandering Albatross	79 (7)*	21(93)	261 (119)
Black-browed Mollymawk	78(82)	22 (18)	232 (141)
Light-mantled Sooty Albatross	100	0	27
Giant Petrels(both species)	88 (89)	12 (11)	227 (64)
Cape Pigeon	72(67)	28 (33)	404 (246)
Snow Petrel	100	0	214
Grey-faced Petrel	0	100	49
Kerguelen Petrel	0	100	40
Mottled Petrel	0	100	14
Juan Fernandez Petrel	100	0	1
Broad-billed Prion	69	31	c.487
Antarctic Prion	100	0	c.565
Thin-billed Prion	0	100	306
Fairy Prion	99	1	1709
Grey Petrel	100	0	13
White-chinned Petrel	35 (51)	65 (49)	13 (9)
Short-tailed Shearwater	0	100	59
Black-bellied Storm Petrel	100	0	21
Wilson's Storm Petrel	100	0	284
			c.4926 (4347)

* Figure in brackets is % with ship's garbage feeding removed: i.e. natural food

120°05′ W, SST 10.4 °C). These same two birds followed the ship due south for 200 nautical miles (to 52° S, 120° W, SST 8.6 °C) and were seen displaying on the water whenever the *Eltanin* stopped for research.

Southern Royal Albatrosses *(D. e. epomophora)* were observed near the New Zealand east coast and off the coasts of Tierra del Fuego – two on 6 Jan 65: 52°52′ S 75°16′ W, SST 9.2 °C and six on 20 Feb 1966 about 20 nautical miles from Staten Island in waters of 7.8 °C. This species was looked for but not seen south of the Polar Front.

Wanderers will eat any edible ship's garbage. Red and orange items (orange peel, cigarette packets), probably mistaken for similarly coloured pelagic food (Harper 1979), attracted attention and were often retrieved from the water and manipulated in the bill for a few seconds. They were not eaten. The handling time for such items was 3-8 s (n = 51).

Surface seizing: This is the most common foraging behaviour of albatrosses. The birds alighted, sometimes heavily, on the water and swam rapidly towards prey with outstretched neck and sometimes opened wings (n = 256). The bill was sometimes opened, presumably in anticipation of prey. Several birds would briefly quarrel over a large single food item, often croaking and bill clappering at nearby smaller Diomedeidae and petrels. Adult birds generally won conspecific disputes, although on six occasions when 2 or 3 Wanderer adults were outnumbered by 7-11 juvenile birds, the young birds successfully plundered the food first.

Adult Wanderers effectively repelled all Procellariidae for floating food, except when White-chinned Petrels *(Procellaria aequinoctialis)* resorted to dive-bombing small groups of Wanderers, startling them long enough to snatch their intended food. Adult giant petrels (*Macronectes* spp.) were twice seen to strike Royal Albatrosses with their opened wings for the same result; on both occasions they were unsuccessful. Body size presumably confers a competitive advantage. However, the smaller species, with their greater manoeuvrability, usually arrived at food first.

If food sank, the albatrosses would attempt to retrieve it by partial tipping, like ungainly ducks, with their heads and necks submerged (n = 8).

Surface diving: Albatrosses submerged briefly with only their wing tips above water (n = 3). I have not seen greater albatrosses dive for food sinking below 1 metre.

At night both Wanderers and Royals were much more aggressive and vocal than during the day. A Cape Pigeon *(Daption capense)* which came too close to one immature Wanderer was abruptly seized by the head, lifted from the water and shaken violently before being released. It retired into the night, apparently unharmed.

The greater albatrosses took surface krill and small squid by snatching mouthfuls of the water containing them. They pursued larger squid (seen to be c.30 cm in length) by gliding on outstretched wings just above the water and dropping noisily on them from a height of less than a metre. To maintain height they used their feet to paddle the water – this feeding behaviour required wind speeds above 15-20 kt. On calm nights, when albatrosses had no manoeuvrability in the air, they hunted by stealth, remaining quietly on the water with their wings closed. They grabbed their prey by suddenly snapping at the water. If this proved unsuccessful, they paddled a few metres and tried again.

Squid were efficiently processed. The maxillary pressure of an albatross's bill is sufficient to disable even large squid, some up to c.40 cm in length. On 11 occasions I saw Wanderers drop motionless squid into the water and leave them for several seconds, before retrieving them to eat. They swallowed squid by raising the head and choking slowly. They also chopped and tore the squid into pieces, using either their sharp bill toma or vigorous head shaking. Dark-plumaged immatures appeared to dismember prey more often than adults, suggesting that manipulation of prey may change with experience. Prey-handling time for squid averaged 30.1 s (range 14.5 s to 2.6 min: n = 11). On 10 Dec (Station 13: 40° S 107°22′ W, SST 12.3 °C) at c.2100 h, four *exulans* were seen in the moonlight catching large squid from the surface about 2-5 m from the stern of our darkened stationary ship. One squid hooked on a line was retrieved and photographed (Fig. 3); Dr P. G. Rodhouse (BAS) has recently identified it from the photograph as *Martialia hyadesi*.

Shallow plunging: On 20 Sep 65 at 1100 h (42°59′ S 154°56′ W; wind 14 kt, swell 2 m; SST 9.5 °C, air 9.1 °C), one submature Wanderer was seen to drop from c.3.5 m into the water, completely submerging. It repeated this behaviour 7 min later. Albatrosses are buoyant in the water – this is an unusual way for them to seek food.

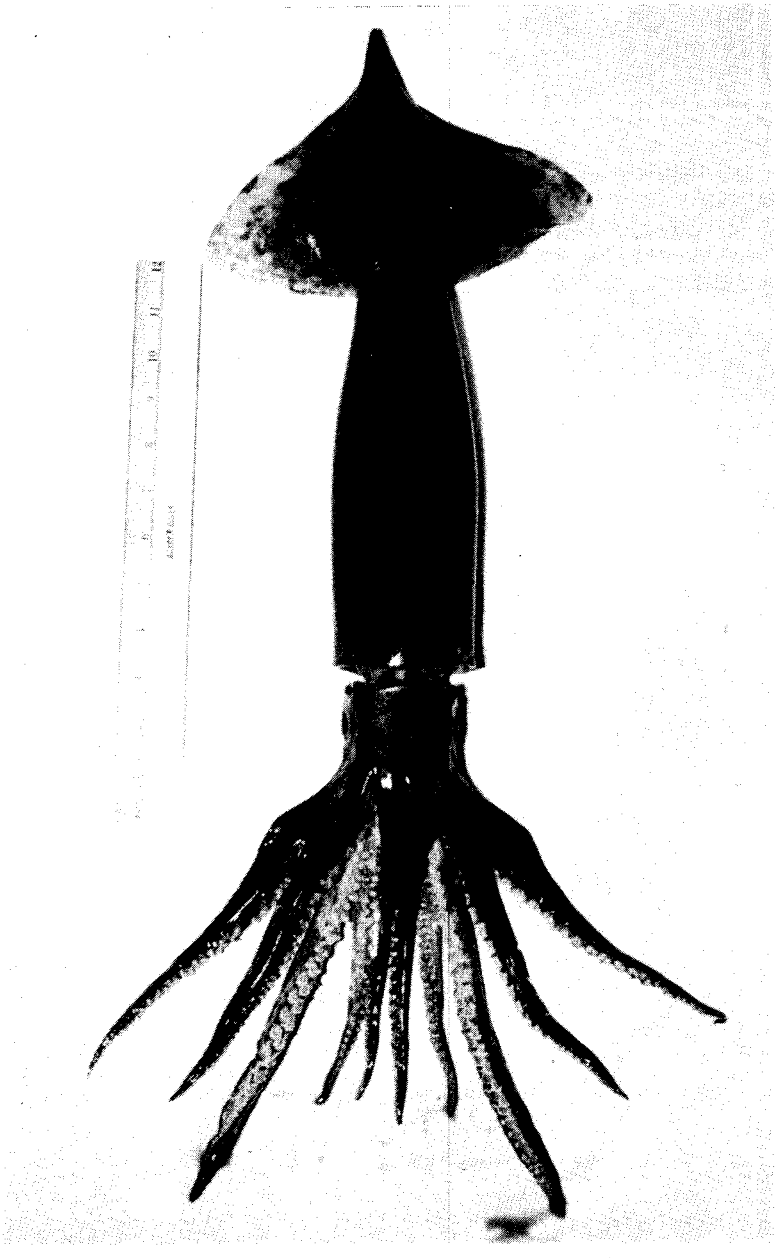

FIGURE 3 — The squid, *Martialia hyadesi*, hooked on a line near foraging Wandering Albatrosses *(Diomedea exulans)* on 10 Dec 1965 (40° S 107°22′ W). See text. An adult Wanderer attempted to retrieve the squid from the line as it was being taken from the water.

BLACK-BROWED MOLLYMAWK *Diomedea melanophrys*
NEW ZEALAND BLACK-BROWED MOLLYMAWK *D. m. impavida*

Black-brows are frequent ship followers, particularly *impavida* in the shelf waters of the New Zealand plateau. The disappearance of dozens of birds from the stern once a ship crosses into deeper waters can sometimes be spectacular. Black-browed Mollymawks are well-known and vocal garbage scavengers and are a good match for giant petrels in contesting food.

Surface seizing: Garbage items, crustaceans, large salps, jellyfish, and salps *Pyrosoma* were taken by surface seizing (n = 227).

Surface plunging: Black-browed Mollymawks surface plunged from heights of 2-5 m after natural prey during daylight hours. They opened the wings immediately after submerging and made no attempt to wing row. The wing tips remained above water. I could not see what food the birds were seeking (n = 4).

Pursuit diving: One immature *impavida* dived from a height of c.6 m into the water directly below the bow of the stopped *Eltanin* and wing-rowed out of sight until it returned to the surface about 20 s later. It had something in its throat which it swallowed before taking to the air (26 Feb 67: 45°30′ S 147°08′ E, wind 12 kt, swell 2 m, SST 13.8 °C). This is the only observation I have of a mollymawk swimming under water.

LIGHT-MANTLED SOOTY ALBATROSS *Phoebetria palpebrata*

Although this small albatross is abundant in the Southern Ocean, I saw it feeding at sea on natural prey on only five occasions, all south of the Polar Front. By day it rarely alighted on the water near the ship.

Immature birds ventured well south of the Antarctic Circle in the Ross Sea near Scott Island during January 1967. My southernmost record is of four immatures on 31 Jan at 71°23′ S 179°06′ W, where the SST was -0.2 °C.

Surface seizing: The albatrosses alighted on the water during the day to search for food among floating garbage in the same way as other Diomedeidae (n = 21). They normally kept out of the way of the other seabirds.

A curious incident occurred on 18 May 1966 (47°34′ S 167°32′ W, SST 10.7 °C). One adult *palpebrata* from an airborne group of 13 alighted near 7 settled *exulans*, which were investigating garbage near the stern of *Eltanin*. On approaching the larger birds, the Sooty was immediately challenged by an adult male and an adult female Wanderer, which clappered their bills and grunted at the newcomer. The Sooty abruptly seized one of its own wings at the carpal flexure and began fiercely savaging it. With its body tilted to one side and slowly beating the air with one foot, the bird battled with itself for 20-30 s, after which it swam away to preen with unusually rapid and jerky movements of its head. After drinking some water, it took to the air.

I have no explanation for this behaviour, except to suggest that the bird was expressing displaced aggression. Prions and the shearwater *Puffinus griseus* in the throes of dying of starvation sometimes fiercely bite their wings just before death.

Surface filtering: Four Sooties were surface filtering among a large concourse of other petrels in a swarm of *E. superba* on 20 Feb 66 (61°44′ S 22°27′ W, SST 1.2 °C – see Harper 1973). They inserted about half their partly opened bills into the water and rapidly sucked water containing euphausiids into their mouths. The euphausiids were retained and swallowed merely by closing the bill.

Surface plunging: On 2 March 1966 (55°24′ S 18°58′ W, 2.3 °C), a flying adult Sooty was twice observed foraging by day like an ungainly tern. While passing the ship, it dropped to the water vertically from a height of c.8 m to seize unknown prey in the water, and immediately took off.

PETRELS, PRIONS, SHEARWATERS, STORM PETRELS

SOUTHERN AND NORTHERN GIANT PETRELS
Macronectes giganteus and *Macronectes halli*

As these two species were not distinguished until 1966 by Bourne & Warham, whose findings were not available to me on the *Eltanin*, I have distinguished my giant petrel sightings below from plumage notes and Ektachrome colour photographs.

Giant petrels, particularly *halli*, are well known as persistent ship followers and scavengers. The increase of their numbers with the rise in wind and sea conditions heralding a cold front was a conspicuous feature of weather conditions during the South Pacific *Eltanin* cruises, and several species of larger petrels clearly gained a wind-assisted passage from one side of the Pacific to the other. This was particularly true of immature giant petrels leaving their nests in the New Zealand region and migrating eastwards across the Pacific in May 1966. They rarely paused by the *Eltanin*, which was punching slowly westward into oncoming gales. During the brief intervals that the wind dropped, the young giant petrels vanished, riding before the wind. The passage of cold front systems and their effect on the distribution and feeding ecology of Procellariiformes clearly require study.

Giant petrels were noisy and belligerent at sea, using their conspicuous aggressive displays to fend off their own kind and smaller petrels gathered about food in the water (see Harper & Kinsky 1978: Fig. 9B). They snapped at smaller seabirds which approached too closely and occasionally beat them with their outstretched wings. One *Daption* was disabled in this way, killed and eaten by an adult male *M. giganteus* on 10 Mar 66 (55°45′ S 42°52′ W).

Wandering Albatrosses and some of the mollymawks presented more of a problem to the giant petrels, however. Giant petrels attempted to win the race for food before these more ponderous competitors arrived; they would abandon food only when directly threatened by the albatrosses.

Giant petrels are day and night feeders. They will attempt to eat almost anything floating on the water; they choked on and regurgitated cigarette packets, paper, orange peel, and floating feathers. When the number of sexes and age groups were about equal, larger adult males would repel females and younger birds from garbage thrown overboard. I have also seen this behaviour among birds congregated about the stern of the Wellington to

Picton rail ferries before their morning departure from Wellington terminal in the 1960s and early 1970s. Young birds were successful in obtaining food only when they outnumbered the adults.

My observations showed that first-year giant petrels moult their flight feathers in December and were in new feather by early April (data from 27 locations in South Pacific and South Atlantic 1965; 1966).

Surface seizing: This is the usual foraging method during the day (n = 193).

At night giant petrels are skilled at catching squid up to 30 cm long (n = 19). A bird grabs the squid with its bill, sometimes impaling it with the maxillary unguis. Having secured the squid, it shakes its head roughly to kill the animal, sometimes moving backwards in the water while doing so. Usually it holds its wings partly open, sometimes draped into the water. It swallows the squid whole or chops it into large chunks and eats it in quick gulps. Two adult *halli* on the water were seen during the day fighting over a large dead squid about 0.8 m in length near Magellan Straits (6 Jan 66: 52°52′ S 75°16′ W, SST 9.2 °C).

Surface filtering: Giant petrels seemed to filter water for small planktonic organisms by gulping a quantity of water and allowing the excess water to flow from the base of the bill at the gape (n = 19).

Surface diving: Giant petrels surface dived to beyond 1 metre, rarely to 2 metres, to wing-row in pursuit of sinking slices of bread and unidentified natural prey (n = 8). In a group of seven giant petrels seen near a fishing boat off Stewart Island in Sep 1976, I observed four *M halli* diving after food while the three *M. giganteus* remained resting on the surface. The possibility that the two species differ in foraging behaviour at sea deserves further study: the food and feeding ecology of the two species at South Georgia, based on food collected from nestlings, has been studied by Hunter (1983).

Surface plunging: Birds flying 2-4 m above the sea by day flopped into the water with only the wing-tips remaining above the surface (n = 7). Giant petrels are very buoyant in the water and can submerge only with difficulty. I do not know what such birds were trying to catch.

CAPE PIGEON *Daption capense*

This noisy and gregarious species forages mostly from the sea's surface. It is a skilled glider, and because of its light body weight and soft plumage, it is buoyant in water. It is attracted to ships both by night and by day and remains near them even during severe gales, when other Procellariidae disappear. I saw Cape Pigeons roosting on icebergs in the Scotia Sea on four occasions. They also sleep on the water by day. For example, I saw a flock of 40 moulting birds asleep on the water in the company of 12 Antarctic Fulmars on 23 Feb 1966 at Station 34 (63°02′ S 14°36′ W, wind 20 kt, sea 1.6 m, SST 0.3 °C). Other Cape Pigeons were sleeping with their bills tucked under their scapulars on small adjacent icebergs.

Surface seizing (n = 169) and **surface filtering** (n = 44): Cape Pigeons investigated all ship garbage and surface seized red and orange objects in the same manner as the Diomedeidae (see Harper & Kinsky 1978: p39).

They also fed on small organisms stunned or disabled by propeller wash or by the discharge of the airgun echo-sounding devices used on the early *Eltanin* cruises.

When foraging for natural prey, Cape Pigeons surface seized with pigeon-like, rapid up-and-down movements of the head, the bill and sometimes the head being inserted into the water. Birds observed closely were **surface filtering**, taking rapid mouthfuls of water into the beak and expanding the small interramal pouch of naked skin. Excess water is forced through the sides of the closed bill by the tongue and collapsing of the pouch. The technique is similar to that of the larger-billed *Pachyptila*, except that the Cape Pigeon's bill is not fringed with highly modified lamellae. It is, however, tight fitting and contains a series of fine serrations.

Cape Pigeon's often used their feet while feeding, paddling with one foot and then the other; sometimes they swam in small circles, using their feet to create water movement to bring small water-borne food to the surface.

Surface plunging (n = 77): This is commonly used to catch prey (mostly squid) on the surface at night. The bird flies swiftly, low over the water, with rapid wingbeats and prolonged glides. When it sees prey, it quickly darts or lunges sideways, often plunging into the water with its wings held out or high over its back for stability. Neighbouring birds are immediately attracted to a catch and noisy squabbles usually result. If a Cape Pigeon is slow in disposing of its catch, giant petrels and larger albatrosses move in to usurp it. I saw this on six occasions when a Cape Pigeon had tried unsuccessfully to fly off with its prey. One of several birds catching squid disabled one, which I was able to retrieve from the water with a net. It was a 109 g *Gonatus antarcticus* (South Atlantic, 10 Mar 66: 55°55′ S 42°34′ W, SST 3.2 °C).

Dipping(n = 58): Dipping is used by Cape Pigeons to take euphausiids from the water. One of a 12 bird flock feeding in this way I managed to attract aboard the *Eltanin* with a 1500 watt signalling light. Its proventriculus was packed with 58 g of *Euphausia triacantha* (11 Oct 65: Station 15: 60°11′ S 122°32′ W, wind 23 kt, swell 2 m, SST 0.6 °C). The bird was an adult female with a bare brood patch and a body weight of 475 g. Another bird attracted to the ship during a snow-storm at 0300 h on 16 Feb 66 (Station 29: 60°02′S 29°59′W, SST 1.0 °C) regurgitated c.22 g of small *E. superba* before being released. The mean length of 30 specimens was 11.1 mm (range 7.2-17.4 mm).

Surface diving (n = 33) and **pursuit diving** (n = 21): Before surface diving Cape Pigeons paddled on the surface with partly opened wings and their heads submerged, presumably scanning for prey below. Crustaceans and small salps were caught in this way.

Such prey was normally eaten at the surface and on five occasions was identified as small squid 50-100 mm in length. One bird surfaced with a large euphausiid, probably *E. superba*. The bird dropped it while regaining the air and a passing Antarctic Prion *(P. desolata)* dipped to retrieve it.

Eighteen night dives averaged 19.1 s (range 7-27 s). Those birds closely observed surfaced under their own buoyancy.

Hydroplaning (n = 2): Two Cape Pigeons close to the ship were seen to scurry forwards on the sea's surface on outstretched wings with their bills briefly immersed in the water and their heads moving rapidly from side to side. I saw nothing large in the water; their prey may have been small translucent copepods which were caught in a plankton net.

SNOW PETREL *Pagodroma nivea*

This Antarctic bird was commonly encountered in high latitudes in water temperatures of about 0 °C, where its favourite haunts are open leads in the ice and around 'bergy bits'.

Snow Petrels foraged at any time of day south of the Antarctic Circle, although possibly less so during the early morning hours (0100-0330 h: n = 14; see also Ainley *et al.* 1984). The lee of large icebergs offered the birds shelter from strong winds and there they foraged undisturbed, sometimes in flocks of several hundred. After feeding, Snow Petrels washed themselves by dipping their heads underwater and funnelling the water over their flattened backs and open wings.

Snow Petrels sat on icebergs, sometimes in hundreds, and remained invisible unless they took to the air. Often a swift and erratic flier, the birds frequently used skimming low dives interspersed with very rapid wingbeats. In this way they could make headway into the teeth of a gale, weaving very quickly from side to side and dipping low to the water to seek respite from the wind. A flock of Antarctic Petrels observed at the same time was flying gull-like strongly and directly into the wind. The birds made no headway, however, and gradually disappeared from view downwind.

In the Pacific, Snow Petrels are normally absent over open ice-free water. I recorded only one, blown north by a southerly gale into waters of SST 5.0 °C at 59° S 120° W on 25 Dec 1965 at 0300 h, in a subsiding S wind of 25 kt.

Dipping: Dipping is commonly used by Snow Petrels to catch euphausiids (n = 141). The euphausiids were large, probably *E. superba*. Sometimes the birds hovered kestrel-like above the water before swooping quickly to the surface. Ainley *et al.* (1984) saw Snow Petrels dipping for prey in the Ross Sea (90% of 35 observations).

Surface seizing (n = 54): Snow Petrels alighted with wings held high over their backs and paddled into the wind with their bills quickly dipping into the water, taking small euphausiids. The capture rate was 15-21 per min (n = 3). Those *E. superba* taken from the *Eltanin's* seawater intakes at the same time as the timed observations were 22-31 mm in length (average 25.2 mm: n = 100).

On 13 Jan 1967, while on Station 5 (70°54′ S 171°50′ E, SST -0.4 °C), 24 nautical miles from Cape Adare, I observed a flock of 30 Antarctic Petrels *(Thalassoica antarctica)* in company with 3 Snow Petrels sitting in the water. Two of the Snow Petrels were clearly much smaller than the other one and were resting very deeply in the water with their tails barely above the surface. One of the smaller birds craned its neck sideways and caught a large euphausiid, which it promptly ate.

Ice gleaning (n = 19): While aboard USCGC icebreakers *Glacier* and *Polar Sea* at the ice edge of the Ross Sea in 1982, I noticed that Snow Petrels took advantage of upturned ice pushed aside by the ships, apparently to retrieve injured or stranded plankton caught in the ice interstices.

GREY-FACED PETREL *Pterodroma macroptera gouldi*

Although a common winter breeder in northern New Zealand, this subspecies is not often seen at sea because it is solitary and swift-winged, it ranges widely in subtropical waters, and it avoids ships. The only remarkable exception to this was one adult female which collided with *Eltanin* in broad daylight (1400 h) on 3 Dec 1966 in the Tasman Sea (40°22′ S 166°24′ E, swell 3 m, wind 25 kt, SST 14.9 °C). Its body weight was 512 g and its stomach was empty (NM 12357). The furthest east I saw one was on 19 Sep 1965, some 2200 km due east of Wellington (42°01′ S 159°27′ W, SST 10.1 °C). They appear to remain in waters warmer than 10 °C on both sides of the New Zealand mainland.

This subspecies fed only at night from the surface of the sea, its main prey being squid and crustaceans.

Surface seizing (n = 27): To catch squid, birds alighted swiftly with wings spread and head stretched forwards. They attacked large squid by lunging, biting, and pulling at them, sometimes impaling them with the bill unguis. One bird, struggling with a large squid, dipped its open wings into the water to act as a brake and hinder its prey from escaping. Three squid killed and eaten seemed about 200 mm in length; the prey-handling times were 14 s, 71 s, and 3.1 min.

Dipping: Grey-faced Petrels dipped and hovered to pick crustaceans from the water. Having secured their prey, the birds briefly rose into the air while eating them (n = 22). I have two sightings of *macroptera* dipping for squid; in both, the birds had to alight to subdue their prey. One squid c.450 mm long escaped from a bird only 2.5 m from me; it immediately resumed feeding, catching two euphausiids in quick succession.

KERGUELEN PETREL *Pterodroma brevirostris*

This widely distributed gadfly petrel, with its distinctive gliding flight high above the sea, was seen on 23 occasions in the Polar Pacific and South Atlantic oceans (full details in Harper *et al.* 1972). During the day the birds remained some distance from the *Eltanin*, except when single birds occasionally investigated us by gliding in over the lee side of the ship.

Dipping (n = 40): Seven birds were seen foraging about our ship shortly after 2300 h on Station 38 (2 Mar 1966 at 55°10′ S 19°02′ W, wind 26 kt, air 0.2 °C, swell 2 m, SST 2.4 °C). The birds wheeled bat-like about the ship, only inches above the water. On sighting something in the water, they would rise slightly in the air, and pause on rapidly beating wings to snatch prey at the sea's surface with their bill. They were probably taking *E. superba*, which were caught in plankton tows at the time. One bird travelling downwind and thus lacking any wind assistance surface-plunged into the water to secure unidentified prey. There was too much wind and surface noise to detect whether squid were present.

MOTTLED PETREL *Pterodroma inexpectata*

The Mottled Petrel has an especially widespread distribution and is the only gadfly petrel to occur in Antarctic and Pacific Arctic waters as far south and north as the ice edge. Although I have seen them associating with mixed flocks of procellariids, including its congener the Soft-plumaged Petrel *(P. mollis)*, which were gorging themselves on krill during the day, I have not once seen Mottled Petrels join in the feast. They appeared and disappeared in their silent, solitary way.

The ice edge seems to interest them, for they will fly regularly along it, sometimes circling particular pieces of brash ice. I have not seen them alight on the water even during the long Antarctic day.

Surface seizing and **dipping:** I have two records of Mottled Petrels catching squid at night.

28 Dec 1965 (Station 20: 61°13′ S 120°09′ W, wind 18kt, swell 2 m, SST 3.5 °C): Shortly after midnight, while *Eltanin* was "steaming on the wire", a single *inexpectata* appeared briefly in the decklights dipping for food (n = 10) very close to the port side where I was standing. It retrieved a squid but then disappeared.

12 Feb 1967 (Station 40: 58°06′ S 154°28′ E, wind 10 kt, swell 2 m, SST 4.5 °C): At 2210 h, one bird, seen alighting and catching prey by surface seizing (n = 4), was caught in a net at the side of the ship but escaped capture by struggling out of the net as it was being hoisted on board. The bird regurgitated the fresh remains of a squid *Moroteuthis ingens*, which was c.12 cm in mantle length.

Ainley *et al.* (1984) saw Mottled Petrels catching squid by pursuit plunging and surface seizing (n = 3) north of the Ross Sea between 2200 h and 0200 h and collected three birds at 68°41′ S 171°49′ W on 27 Dec 1979. These birds contained beaks of the squids *Gonatus antarcticus* (n = 3) and *Galiteuthis glacialis* (n = 5) together with an otolith from the fish *Pleuragramma antarcticum*.

JUAN FERNANDEZ PETREL *Pterodroma externa*

This large subtropical species was recorded daily from when the *Eltanin* left Mas Afuera Island on 25 Nov 1965 (Cruise 21) to well out into the South Pacific at 120° W and south until 19 Dec 65 at 50° S 120° W, SST 9.5 °C. At this latitude the birds were in the company of flocks of 10 White-headed Petrels and single White-chinned and Grey Petrels.

One bird from a mixed flock of 40 Juan Fernandez Petrels and Sooty Shearwaters was seen to alight briefly to feed on unknown prey at 1300 h on 11 Dec 65 (39°55′ S 109°35′ W, SST 14.6 °C). Occasional *externa* were seen flying about the *Eltanin* at night, but I did not see them feeding.

PRIONS (genus *Pachyptila*)

This widespread and abundant group of petrels was intensively studied during the *Eltanin* voyages and I have already discussed the identification, distribution, taxonomy, feeding habits and food of the prions (Harper 1972, 1976, 1978, 1980; Harper & Kinsky 1978; Harper & Rowlett 1983).

Prions are surface feeders and, in keeping with their differing bill structures, feed in different ways. In the Pacific they normally associate with ships only if the vessels are stopped in the water. Once, however, a group of 16 Antarctic Prions followed us, weaving like bats in the wake of the USCGC *Glacier*, which was steaming at 5 kt on 5 Feb 1982 (59°50′ S 173°28′ E) south-east of Macquarie Island. They remained with the ship for 20 min and were photographed at close range before they disappeared from view.

BROAD-BILLED PRION *Pachyptila vittata*

This gregarious species was seen in mixed flocks with Fairy Prions and Fulmar Prions from 10 to 29 March 1967 when the *Eltanin* made a transect crossing, at 43° S, of the Tasman Sea from Tasmania to near Westland (Cruise 28). It feeds by hydroplaning and surface seizing.

Hydroplaning (n = 251): The Broad-billed Prion filters minute plankton from water sucked into its partly opened bill by rapidly lowering the large fleshy tongue and expanding the distensible interramal pouch. It then shuts its beak and forces the water through the palatal lamellae, which retain any food. In large swarms of copepods, flocks of *vittata* alighted to pirouette in the water while they fed, birds sometimes twisting sideways to pick off copepods adhering to their plumage.

Surface seizing: Although its bill is a superbly adapted filter, *vittata* also catches larger prey such as euphausiids and squid. Euphausiids were collected individually (n = 22) or if very small (<8 mm, as in plankton tows) by surface filtering like *Daption* (n = 14).

Surface plunging: On 16 Mar 1967 at Station 10 (43° S 156° E, wind 10 kt, SST 15.2 °C) at 2100 h, I watched a flock of c.200 Broad-billed Prions catching small squid up to 50 mm in length by surface plunging only a few metres from the side of the ship. One bird briefly wing-rowed under water in pursuit of prey for 4-5 s before returning to the surface with a squid held in the bill. The edges of the maxilla are sharp in *vittata* – excellent for clamping squid.

ANTARCTIC PRION *Pachyptila desolata*

In the South Atlantic this species commonly feeds by day during the summer months on krill *(E. superba)*. In 565 observations of feeding behaviour I have seen the Antarctic Prion catch only krill, and I have not recorded it feeding at night. Prince (1980) found that 90 samples of food brought to chicks on Bird I., South Georgia, consisted by weight of 97% crustaceans (59% Euphausiacea, 37% Copepoda, the remainder Amphipoda and Mysidacea) with 3% fish and squid. The paucity of squid in this diet also suggests that this species forages mostly by day in the Scotia Sea Region during the chick-rearing period.

In the Scotia Sea during Cruise 22, pieces of floating kelp were seen to attract the attention of Antarctic Prions, which alighted to peck at them, perhaps because barnacles were present or because small planktonic organisms had briefly adhered to the kelp's worn rough surface.

Surface seizing: The Antarctic Prion surface seizes individual adult krill

(South Atlantic Cruise 22: n = 402); on six occasions I saw birds take to the air with large euphausiids held crosswise in their bills. Three birds attracted aboard *Eltanin* during a night snow-storm on 16 Feb 66 (Station 29: 60°02′ S 29°59′ W, SST 1.0 °C) regurgitated *E. superba* with a mean length of 12.2 mm (range 7.9-19.7 mm; n = 171).

Hydroplaning and **surface filtering:** Antarctic Prions took smaller unidentified prey (small euphausiids or copepods?) by hydroplaning (n = 96). Their surface filtering is exactly the same as that described for *Daption* (South Atlantic Cruise 22 Feb 66: n = 79; also near Macquarie I. Feb 67; n = 5).

Surface diving: Birds sitting on the water surface dived to avoid the oncoming *Eltanin*; they also surface dived to gather unidentified prey from below the surface (n = 21).

Dipping: I have two daylight observations, on 11 Feb 66, 285 nautical miles WNW of the South Orkney Is, of small groups of *desolata* dipping for euphausiids (n = c.41).

THIN-BILLED PRION *Pachyptila belcheri*

Full details on the *Eltanin* records of this species, including their feeding habits, have been published (Harper 1972). The main prey for birds in the Pacific area seems to be the amphipod *Themisto gaudichaudii*; other prey items include the myctophid fish *Electrona* and small squid. Strange (1980) also reported that euphausiids are an important food for chicks at the Falkland Islands. Food is obtained at night by **surface seizing** (n = 131), **dipping** (n = 77) and **pattering** (n = 98).

FAIRY PRION *Pachyptila turtur*

Fairy Prions are common in the offshore waters of New Zealand and frequent in the Tasman Sea (Harper 1976). I have 1709 observations of them foraging at sea; 1698 (99.35%) of these were made by day. Foraging behaviour includes **surface seizing** (n = 901), **dipping** (n = 756), **pattering** (n = 48), and **surface plunging** (n = 4). On 63 occasions, where plankton tows were done concurrently with the observations, the food was probably the euphausiid *Nyctiphanes australis*.

GREY PETREL *Procellaria cinerea*

This winter-breeding species was a key indicator of subantarctic waters in the Pacific. I saw many but rarely in groups of more than three or four. Birds in the mid-Pacific in September and October 1965 were all in fresh plumage and were probably non-breeders; those seen closer to the South American coasts two months later, in December, were all in worn feathering and were probably post-breeding adults.

Deep plunging: The only time I saw Grey Petrels feeding was at 1200 h on 22 Sep (44°51′ S 145°20′ W, SST 8.62 °C) while we were stopped on Station 1. A group of male and female killer whales *(Orcinus orca)* drifted by the ship accompanied by 13 Grey Petrels. The sea was calm and the birds were diving into the water near the whales from about 3 m. I could not see what the birds were feeding on, but trawls at the same time yielded small crustaceans and fish.

WHITE-CHINNED PETREL *Procellaria aequinoctialis*

Widespread and abundant in subantarctic waters, this species is a bold and courageous competitor for food. Groups of up to six birds unhesitatingly plunged into a group of albatrosses with the intention of driving them off their food. This species also competed with the much bigger *M. giganteus* for squid by grabbing prey from the larger bird's beak. This twice resulted in the squid being torn in two and both birds retiring with their meal. A shrill chattering is occasionally given by birds at sea. White-chinned Petrels are opportunistic foragers using a combination of techniques to catch their prey.

Surface seizing: Birds took offal from fishing boats by alighting in the wake and surface seizing, or took crustaceans and squid from the sea's surface at night in the same way (n = 11). One bird was observed from only 2 m distance while it gathered at least 24 euphausiids in just under a minute.

Deep plunging: While in the South Atlantic on 1 Feb 1966 (52°36′ S 52°16′ W, swell 1 m, wind 15 kt, SST 8.2 °C) I saw a large group of c.150 Peron's dolphin *(Lissodelphis peronii)* erupt from the water near the *Eltanin*, possibly startled by our presence. Two White-chinned Petrels deep-plunged into the water vacated by the dolphins, but I could not see what the birds were catching and I did not see them resurface – the ship was under way at the time.

SHORT-TAILED SHEARWATER *Puffinus tenuirostris*

This species was observed only near the east Australian coast and in large numbers only near Macquarie Island during Cruise 27 in Feb 1967. It feeds chiefly by pursuit diving and has a relatively heavy body mass to counteract natural buoyancy. An immature male with an empty gizzard was collected in daylight on 12 Feb at Station 40 at 58° S 154° E. On Station 40 a small flock was observed foraging under the decklights for 21 minutes.

Pursuit diving (n = 26) and **deep plunging** (n = 33): At least 14 birds were foraging by pursuit diving and deep plunging after squid which I could see in the brilliantly lit water around our vessel. Those birds which were on the sea's surface immersed their heads and scanned for prey while paddling slowly forwards. On seeing prey, a bird would immediately paddle powerfully forwards, pushing the front part of its body high off the water before plunging below and wing-rowing quickly out of sight.

Following one bird's dive was difficult because many birds were diving and they often reappeared at the surface up to 15 m from where they entered it. Six dives followed to completion were timed at 6-15 s (mean 8.8 s). On each of these I saw the bird assist its passage back to the surface with rapid strokes of its wings. This was in marked contrast to the more buoyant species such as *Daption*, which return to the surface solely by natural buoyancy. Fluttering Shearwaters *(Puffinus gavia)* catch small fish in Wellington Harbour in exactly the same way as described here for *tenuirostris*.

BLACK-BELLIED STORM PETREL *Fregetta tropica*

Although this storm petrel was often seen during the *Eltanin* voyages, I saw foraging only once. During the Tasman Sea Cruise on 11 Dec 1966

(1720 h) at 45° S 160° E a bird was seen, about 7 m from our stationary ship, **dipping** (n = 21) in a 20 kt wind and sea 3 m. The prey appeared to be small crustaceans.

WILSON'S STORM PETREL *Oceanites oceanicus*

This very common species was often seen foraging near the stern while the ship was on station. The prey was usually too small to be identified. Two feeding behaviours predominated: **pattering** (n = 207) and **dipping** (n = 77). Nine specimens were collected, mostly from the Feb 1966 Scotia Sea Cruise 22; two of these obtained from Station 29 (17 Feb 66 at 0200 h: 60° S 33°05′ W; SST 1.0 °C, swell 1 m, wind 13 kt) and offshore from South Thule Island, South Sandwich group, on 18 Feb 1966 (59°28′ S 27°16′ W) contained small *E. superba* with a length of 6.1 mm (range 5.1-9.7: n = 60). The remaining specimens had gizzards containing only 3-9 small pumice gastroliths.

COMMENTS AND CONCLUSIONS

1. The long-held belief that petrels feed at night is confirmed for Wandering Albatrosses, Giant Petrels, Cape Pigeons, Grey-faced Petrels, Kerguelen Petrels, Mottled Petrels, Thin-billed and Fairy Prions, White-chinned Petrels, and Short-tailed Shearwaters. These species represent seven distinct genera with differing evolutionary and feeding strategies. Thus, although nocturnal feeding is probably widespread among the Procellariiformes as a whole, more information is needed to confirm this.

2. The presence of nocturnally feeding petrels was confirmed by observing them directly under the decklights, by spot-lighting them near the darkened ship with the bridge signalling lights, and by observing them under moonlight. A modern image intensifier could greatly aid future work on the nocturnal habits of petrels at sea.

3. The six species observed feeding exclusively by day were Light-mantled Sooty Albatross (n = 27), Juan Fernandez Petrel (n = 1), Antarctic Prion (n = c.565), Grey Petrel (n = 13), Black-bellied Storm Petrel (n = 21), and Wilson's Storm Petrel (n = 284). The Snow Petrel was seen feeding only during the Antarctic day (n = 214).

4. Five species scavenged the galley refuse for food during the day. If these observations are removed from the Wandering Albatross data, 93% of the remaining 141 feeding observations were at night. This suggests that, although albatrosses are conspicuous scavengers by day, most of their food is live prey (squid and crustacea) captured at night from the sea's surface.

Prince & Francis (1984), using activity recorders attached to 13 South Georgian Grey-headed Mollymawks *(Diomedea chrysostoma)*, have shown that on 284 bird-days the birds foraged at sea during February 1982, they spent an average of 74% of the time flying and 15% of the day and 50% of the night on the sea. Because about half the mollymawk's diet is squid, they concluded that "The extensive nocturnal activity on the water strongly supports suggestions that the species feeds mainly at night".

5. Weimerskirch *et al.* (1986), in assuming that surface-seizing seabirds such as albatrosses are "unlikely" to catch fast-moving prey such as squid, postulated that most of squid prey taken by albatrosses were dead and floating on the surface where albatrosses might scavenge for them. They continued, "This assumption is supported by the fact that some of the cephalopod species found in the chick samples are thought to occur only in deep water and would consequently only be available for albatrosses after their death". Clarke *et al.* (1981) have discussed the possibility that deep water squid might be obtained by seabirds through sperm whales vomiting their stomach contents when approached by humans or to empty them of cephalopod beaks which apparently do not pass further down the gut. Hence, "it is not rare for whalers or marine biologists to observe freshly vomited cephalopods floating on the sea surface even without a sperm whale being actually chased."

While marine birds undoubtedly scavenge dead squid, my observations suggest that live squid are present at the sea's surface much more commonly than is realised. They appear to be a normal predatory component of the vertical planktonic migration to the surface after dark, although large seasonal fluctuations in their numbers probably occur. Some intermediate-sized mesopelagic and deep water species of squid which follow krill swarms to the surface could conceivably become available to avian predators directly, rather than indirectly by dying and floating to the surface as suggested by Weimerskirch *et al.* (1986) or being transported there by sperm whales (Clarke *et al.* 1981). Because albatross bill morphology and behaviour clearly make them skilled at catching live squid, I believe that most of their squid prey is taken actively. Very large squid could only be scavenged from the sea's surface, however.

Because squid appear to be relatively easy for birds to disable (i.e. they bleed freely once their body wall is punctured), it seems highly likely that some cephalopods might be injured by a nocturnal avian predator, escape, and die later from their injury. A flock of birds catching squid might disable a large number at the surface. Such animals would presumably have to remain on the sea's surface because, at the very least, of water pressure at depth; hence, after sunrise they would become easy pickings for passing birds. I am suggesting that squid die through injury at the surface rather than die at depth and drift to the surface as suggested by Weimerskirch *et al.* (1986). Clearly much more information on all these matters is needed.

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SHORT NOTE

Welcome Swallows breeding near Te Anau

In October 1985 Welcome Swallows *(Hirundo tahitica neoxena)* attempted to breed for the first time in the Te Anau district. Welcome Swallows built three nests under a wooden bridge on Stony Creek c. 11 km east of Te Anau. However no eggs were laid (R. B. Lavers, R. G. Thomas, pers. comm.). For a few weeks in spring 1986 three Welcome Swallows were flying around the bridge but the birds did not nest (R. G. Thomas, pers. comm.).

On 30 November 1986 I found Welcome Swallows nesting under a concrete bridge 5 km south of Te Anau on the Te Anau-Manapouri main road. Two nests were empty but the third held three small downy nestlings. They were seen again on 4 December, 10 December and 11 December, when two adults were feeding them. On 12 December at 1740 hours the chicks were gone but at 2130 hours (dusk) they were roosting in the nest with their parents. The three juveniles were perched on the power line by the bridge on 16 December.

A second nest held three nestlings with their first feathers on 17 January 1987. These chicks were fully feathered and overlapped their nest by 22 January and 24 January. The nests were empty on 29 January and have remained so on several later visits up to May 1987. Only two adults were present throughout both nesting periods.

KIM MORRISON, *Box 29, Te Anau*

OBSERVATIONS OF BREEDING BEHAVIOUR OF SPOTLESS CRAKE *(Porzana tabuensis)* AND MARSH CRAKE *(P. pusilla)* AT PUKEPUKE LAGOON

By GERALD KAUFMANN and ROGER LAVERS

ABSTRACT

Spotless Crakes and Marsh Crakes were studied by R. Lavers, April 1971-July 1972, and by G. Kaufmann, September-December 1982, at Pukepuke Lagoon, Manawatu. Eleven Spotless Crake nests were found. Eggs were laid between 30 August and 19 December. Earlier nests usually contained 3 eggs; later nests contained 4-5 eggs, and the eggs were larger. Copulation and major calls are described. One male incubated 40%, the female 60%, of the 35 hours observed. Eggs of 4 nests were eaten by predators. Two Marsh Crake nests were found, containing 4 and 6 eggs. Both nests were unsuccessful. Analysis of museum skins highlighted similarities in bill size and structure, suggesting that interspecific competition occurs.

INTRODUCTION

The breeding behaviour of the Spotless Crake *(Porzana tabuensis)* and Marsh Crake *(P. pusilla)* has remained unknown because of the birds' secretive nature, their dense habitat, and their lack of obvious sexual dimorphism. The presence of two species of *Porzana* so similar in size and shape in the same wetlands in New Zealand is intriguing because it seems to violate the ecological rules of competitive exclusion or character displacement. Aggression between Spotless Crakes and Marsh Crakes, although believed uncommon, has been observed (Howard 1962). Our study sought to record aspects of their little-known biology from a single wetland in which both species occurred.

STUDY AREA AND METHODS

Pukepuke Lagoon is an 86 ha game management reserve of the New Zealand Wildlife Service in the Manawatu. It is a swampland within the coastal sand dune area. The dominant emergent plants are raupo *(Typha orientalis)*, flax *(Phormium tenax)*, tussock sedge *(Carex secta)* and cabbage tree *(Cordyline australis)*. The vegetation, climate, and history of the lagoon have been described by Ogden & Caithness (1982).

The crakes were studied by R. Lavers from 28 April 1971 to 25 July 1972 and by G. Kaufmann from 13 September 1982 to 29 December 1982. Drift traps, described by Lavers (1971), were placed in the swamp before the nesting season in an attempt to mark crakes and monitor their movements. In 1971 up to four traps were placed along wire mesh leads in five sites; in 1982 up to four traps were widely scattered in the swamp and attended for long periods. We measured the exposed culmen, tarsometatarsus, and middle toe plus claw of all crakes captured. Coloured plastic bands and numbered metal bands were placed on the crakes. Tape recordings of Spotless Crake calls were used to lure birds toward the traps. Nest traps were placed on active nests to capture incubating birds.

In 1971 a tower hide was placed beside a large patch of willows (*Salix* spp.) west of the main lagoon before the nesting season. From this R. Lavers observed two Spotless Crake nests. Hides were also placed near two Spotless Crake nests in 1971 and two Spotless Crake nests and one Marsh Crake nest in 1982. We used tape recordings and whistling imitations of their calls to find where crakes were and to find nests. Nest searching was concentrated in the areas that included tussock sedge. The names used to describe Spotless Crake vocalisations were taken from the descriptions by Hadden (1970 and pers. comm.). Sonograms were made on a Kay Elemetric Sona-graph.

G. Kaufmann measured study skins at the National and Canterbury Museums. Only those taken from the North and South Islands were measured. The length, width, and depth of Marsh Crake bills were compared with Spotless Crake bills. Specimens with reliable sex identification were used to compare the lengths of male and female culmens and metatarsi.

RESULTS

Trapping

Nineteen Spotless Crakes and five Marsh Crakes were captured and banded during the study period. Five Spotless Crakes were recaptured once; one Marsh Crake was recaptured three times.

In autumn 1971, 13 crakes were caught in 65 trap days. Thereafter few were trapped and the capture rate during the breeding season was particularly low, only four Spotless Crakes and Marsh Crake being captured during 233 trap-days between 21 September and 24 December 1982. Tape recordings did not lure birds at this time.

Nest trapping was unsuccessful, Spotless Crakes would not enter nest traps consisting of a trapdoor with three sides of nylon mesh. Several entered a small clap trap placed on one nest but it failed to spring. G. Kaufmann caught one Marsh Crake by hand after it made repeated attempts to attack his hand.

Marsh Crake calls

The repertoire and function of the calls of both species is incompletely known. Both species give a loud call of many short notes. The loud call of the Marsh Crake is a *creak*, reminiscent of a fingernail being drawn against the teeth of a comb. According to Feindt *in* Cramp & Simmons (1980) and Glutz *et al.* (1973), it is the song or territorial call, given only by the male. At Pukepuke it was the only Marsh Crake call heard, usually given in response to tapes of both species.

Spotless Crake calls

The high-pitched trilling *purr* of Spotless Crakes appears to be its song. It consists of a rapid series of notes, about 25 per second, with a slight and rapid initial decrescendo of pitch (Fig. 1A). It was louder than any other call, but occasionally was given softly. Often both members of the pair were present, as evidenced by duetting of soft calls, but only one member, presumably the male, uttered *purr* and *pit-pit.*

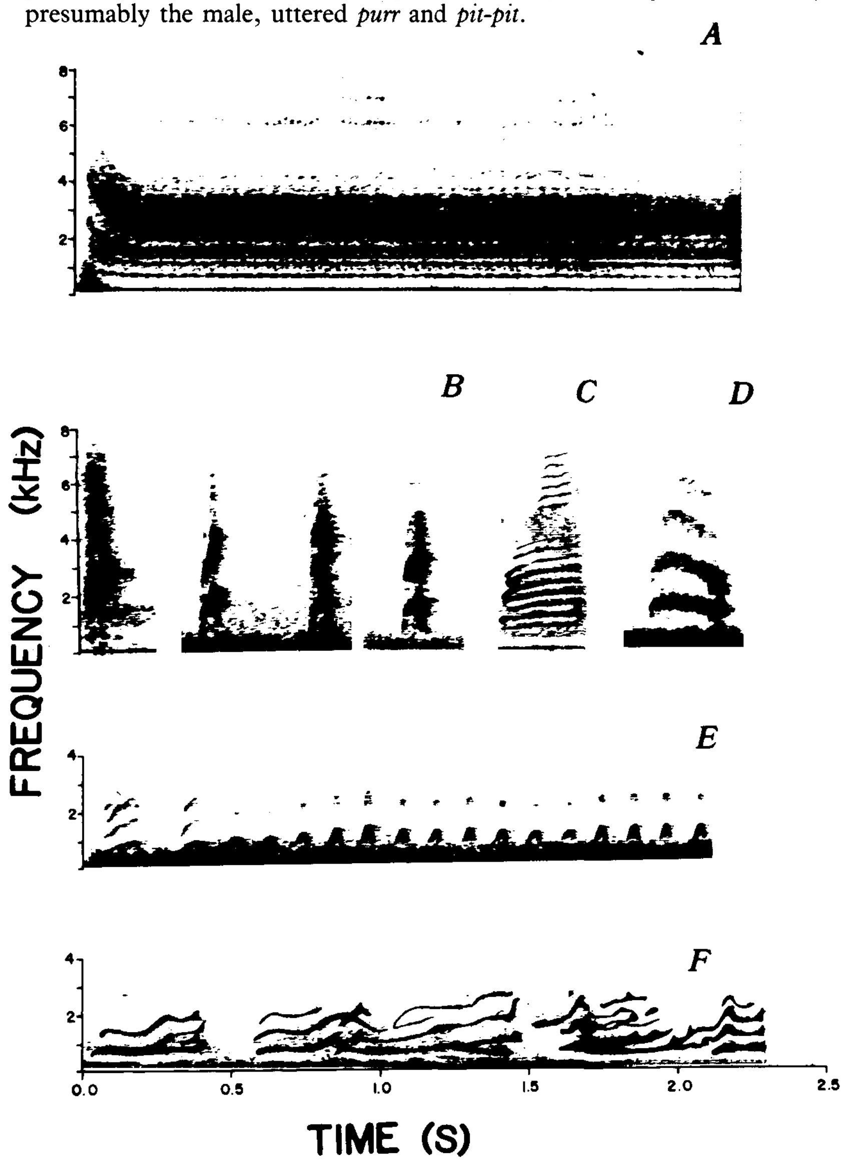

FIGURE 1 — Calls of Spotless Crake: A. high-pitched trilling "purr"; B. variations of loud 'pit'; C. nasal "harring" (slightly retouched); D. a short trilling whistle; E. a "mook" call, and intermediate "mook-bubble" and a series of bubbling; F. two birds duetting a "murmuring" (slightly retouched).

Pit-pit was a loud call lasting only 0.1-0.3 s, covering a wide band of frequencies but typically loudest at 1.75 and 3 kHz (Fig. 1B). It appears to be the 'harsh, scolding crack-crack' described by Falla *et al.* (1981).

On several occasions, both members of the pair approached the tape recorder, and then retreated to the centre of the territory and called *purr*. On other occasions, a crake responding to *pit-pits* on the tapes stopped calling, as if intimidated, when *purrs* were played on the recorder. At times crakes gave *purrs* and *pit-pits* as they approached the recorder, and presumably trespassed a neighbour's territory. These birds gave loud, short calls interrupted by splashing and fighting. Birds near four nests gave the most vociferous and prolonged responses to tapes during the two weeks before incubation began. Loud calls ceased during incubation and birds of adjoining territories came closer to the recorder, presumably "trespassing". No responses were ever given by a fifth pair. The loud *purrs* and *pit-pits* began in mid-July and persisted through to December.

Pit-pits were sometimes interspersed with other short, loud calls. These included *harr* and a short trilling whistle (Fig. 1C and 1D). The trilling whistle was also given in response to a human whistle.

Soft calls, which were low in pitch and amplitude, appeared to function in pair contact. *Bubbling* and *murmuring* were frequently given in duet by two birds near each other, presumably the pair. They seemed to be a milder form of reaction to taped calls, and were commoner after incubation. Occasionally the *mook* graduated into *bubbling*, but *murmuring* appears to be distinct from bubbling (Fig. 1E and 1F).

Sexual behaviour of Spotless Crakes

Few observations of territorial and courtship behaviour have been made because of the dense vegetation. The few observations, such as a chase and calls, are hard to interpret because the sexes are alike.

One pair of Spotless Crakes was seen copulating about 18 metres from their nest. A *purr* and *pit-pit* were heard immediately before the birds came out into the open. The male followed the female around a *Carex* pedestal, which was about at the level of the water. The female circled the pedestal several times and then stood on it, arching her body with her bill pointing downward. After a few seconds the male mounted and, balancing with outstretched wings, slowly lowered himself. Intromission took a few seconds, after which he dismounted and walked into the vegetation. The female stretched her head up and followed the male. This pair was in the middle of egg laying. The clutch was completed two days later and contained five eggs.

Nest site and construction

Eleven Spotless Crake nests, two Marsh Crake nests, and a large number of empty nests were found at Pukepuke in tussock sedge. They were usually in tussocks with well-covered pedestals, with the nest beside the pedestal in tillers two or more years old and on the lee side where wind had laid a thick sheath of tillers over the nest. Several nests of Spotless Crake were on the crown of tussock sedges, on tillers which stretched between two tussocks, or on tillers windblown into raupo. The two Marsh Crake nests were 40 cm above the water, and most Spotless Crake nests were 40-50 cm (range 7.5 to 70.0 cm) above the water. Some nests slipped down with use, and one nest was barely above the water. The nest bowls of both species were usually made of pieces of sedge cut or broken into 1.5-2.0 cm lengths. Several nests included pieces of adjoining raupo. The bowls of some Spotless Crake nests were so loosely woven that, if they had not contained eggs, they would have been judged incomplete.

Most, but not all, Spotless Crake nests were within a few metres of other apparent nests. The functions of these presumptive nests are not known. They were made before egg laying, as they were present during laying. They were used for brooding chicks, and we recorded a pair using one that another pair had made.

Laying and incubation

Active nests of Spotless Crakes have been found from 23 August to 31 January in New Zealand (Hadden 1970, Fraser 1972). Spotless Crake nests found at Pukepuke were active from 30 August to 4 January (Table 1). The many empty nests found later in the season indicated that more had nested in September-October than is reflected by our findings, which got better as the season progressed.

Less is known of the nesting season of Marsh Crakes. The Marsh Crake nest at Pukepuke found on 4 October had a full clutch being incubated. It was destroyed five days later. The inactive nest found in December had rotten eggs that soon burst by themselves. They contained partly developed embryos. In Southland, one brood has been seen on 6 November and an active nest has been found on 25 November (Barlow & Sutton 1975).

The later clutches of Spotless Crakes were larger than earlier ones, increasing from 3-egg clutches in August and September to 5-egg clutches in December (Table 1). Other workers have had similar findings. Hadden (1970, 1972) found five clutches of 2 and 3 eggs, which hatched in September and October, and a clutch of 5 eggs, which hatched on 5 December. Fraser (1972) found two clutches of 3 eggs, of which one hatched in September and one on 31 January, and a clutch of 4 eggs, which hatched in January.

Eggs laid later in the nesting season were significantly larger than those laid earlier (Table 2). The eggs of nests 9, 10, and 11 were 4-5% larger than those of nests 4, 5, and 7.

The shape of Spotless Crake eggs varied greatly within a clutch (Table 2). The eggs of nest 6 weighed 9.0 g, 9.1 g, and 9.5 g; the eggs of nest 11, weighed on a less precise scale, were 8, 8, 9, 9, 9 g ± 0.5. These eggs were each approximately one-fifth of the female's body weight. The Marsh Crake eggs were slightly smaller than the average of Eurasian birds but well within their size range (Cramp & Simmons 1980).

Some Spotless Crake nests hatched slightly asynchronously, and others hatched synchronously. Asynchronous hatching was observed by Hadden (1970, 1972) in two 3-egg clutches and one 5-egg clutch, by Fraser (1972) in a 4-egg clutch, and by us in a 4-egg and a 5-egg clutch. Synchronous hatching was observed by Hadden (1970, 1972) in a 2-egg and a 3-egg clutch and by us in two 3-egg clutches.

The extent of asynchronous hatching was hard to find out because the birds often left an infertile egg in the nest or an abandoned one after disturbance. We assumed that incubation began when the last egg was laid, in synchronous hatchings, and when the second (three cases) or third (two cases) egg of the clutch was laid, in asynchronous hatching.

Incubating birds were difficult to study because they are monomorphic, approach the nest from opposite the hide, and build a canopy over the nest. We had to part the canopy before each observation period. One member of a Spotless Crake pair which nested beneath R. Lavers' hide had been banded and was presumed to be a male because of its size (Table 3). He was observed in the nesting area 8 days before nest building began. This male incubated for 40.4% and the female incubated 59.6% of 35.4 hours of observed daylight time (Fig. 2). The longest uninterrupted spells of incubation were 106 min by the male and 160 min by the female. The actual bouts of incubation were longer for both sexes and characterised by 1-4 breaks. Three long bouts for the male were 116, 145, and 225 min with 1-2 breaks of 5-21 min. Five long bouts for the female were 130, 138, 154.5, 179, and 189 min with 1-4 breaks of 1-26 min.

TABLE 1 — Nesting and incubation period, clutch size, and hatching results of Spotless Crake and Marsh Crake nests at Pukepuke Lagoon

Nest No.	Laying	Hatching	Clutch Size	Hatching Results
Spotless Crake				
1	30/8 to 1/9/71a	22/9	3	3 chicks
2	14 to 16/9/71	6/10	3	2 chicks 1 unhatched egg
3	Before 22/9/82	---	1(+?)	egg predation
4	30/9 to 1/10/82a	22/10	3	3 chicks
5	31/9 to 1/10/82a	23/10	4	4 chicks
6	3 to 5/10/71a	26/10	3	3 chicks
7	17 to 20/10/82a	10/11	4	4 chicks
8	Between 10/10 and 8/12/82	---	4	egg predation
9	6 to 10/12/82	31/12	5	egg predation
10	12 to 16/12/82	4/1	5	5 chicks
11	15 to 19/12/71	---	5	egg predation
Marsh Crake				
12	Before 4/10/82	---	6	egg predation
13	Before 1/12/82	---	4	deserted?

a = estimated from the date of hatching as 1 egg laid per day and 21 days of incubation.

TABLE 2 — Egg sizes of crakes at Pukepuke Lagoon

Nest No.	Egg Sizes	Mean Size	SD
Spotless Crake			
4	28.9 x 23.3	29.4 x 22.8	0.87 x 0.47
	30.4 x 22.4		
	28.9 x 22.6		
5	29.3 x 22.3		
	28.9 x 22.5	28.9 x 22.5	0.39 x 0.17
	29.1 x 22.4		
	28.4 x 22.7		
7	28.0 x 20.2		
	26.8 x 20.6	28.1 x 20.6	1.31 x 0.28
	27.6 x 20.8		
	29.9 x 20.8		
9	29.5 x 23.2		
	28.1 x 22.3	29.2 x 22.7	0.66 x 0.50
	29.5 x 22.0		
	29.3 x 23.0		
	29.8 x 22.8		
10	30.2 x 23.3		
	30.6 x 23.1	30.3 x 23.1	0.63 x 0.15
	31.3 x 23.0		
	29.8 x 23.1		
	29.8 x 22.9		
11	30.9 x 22.3		
	31.1 x 22.5		
	31.3 x 23.3	31.0 x 22.8	0.30 x 0.38
	31.3 x 22.9		
	30.6 x 22.8		
Total R	26.8-31.3 x 20.2-23.3	29.6 x 22.4	1.20 x 0.87
Early nests		28.7 x 21.9a	1.02 x 1.05
Late nests		30.2 x 22.8b	0.92 x .39
Marsh Crake			
12	28.5 x 19.8	28.6 x 20.0	.07 x .21
	28.6 x 20.1		
13	27.7 x 19.4		
	26.9 x 18.9	27.4 x 19.5	.89 x .42
	28.4 x 19.9		
	26.5 x 19.6		
Total	26.5-28.6 x 18.9-20.1	27.8 x 19.6	.89 x .43

a,b There was a significant difference between means of a and b from a t-test.

Information on incubating Marsh Crakes was less conclusive. On the first day of observation the nest was hidden by overhanging tillers and a canopy. After 23 min a crake went to the nest. After 20 more min a bird left, and no more birds were seen in the next 90 min. Either one bird had returned, incubating for 20 min and left, or a bird already incubating was joined by its mate in the tussock after 23 min and the incubating bird left after 20 min. The next day G. Kaufmann captured and banded one bird, presumably the female because of her size and defensive behaviour. The tillers overhanging the nest were cut and the canopy parted; however, the birds were still hard to see because they had added to the rim of the nest. Two hours later, when observations were resumed, the female was on the nest, and crouched low in the nest. The male came to the nest 63 min later and both remained in the tussock. The female continued to incubate while the male alternated between breaking off pieces of sedge and presenting them to the female and resting near the nest in overhanging tillers. After 52 min the male began to incubate. As darkness approached, the female left the tussock 26 min later and began to feed. The next morning the male was observed incubating for 2 hours. By the following day, the nest had been preyed upon.

TABLE 3 — Comparison of male and female culmen and tarsometarsus from museum skins of New Zealand specimens. Measurements in mm ($\bar{x}$;n)

	Male	Female
Spotless Crake		
Culmen	18. 2-20.8 (19.6; 8)	16.3-17.1 (16.6; 3)
Tarso-metatarsus	31.3-33.1 (28.2; 8)	29.0-33.5 (30.6; 5)
Marsh Crakes		
Culmen	17.4-18.9 (18.1; 5)	15.7-19.2 (17.1; 9)
Tarso-metatarsus	28.0-30.7 (29.1; 5)	24.6-29.1 (26.9; 10)

Nest defence

Spotless Crakes reacted to intrusion by leaving the nest when the vegetation above it was disturbed. The bird remained nearby and just out of sight in the vegetation. Usually a definite splashing could be heard. Hobbs (1967) suggested "falling stone display" to describe this action; however, it may be homologous to "churning" observed in the Sora *(Porzana carolina)* and American Coot *(Fulica americana)* (Gullion 1952, Kaufmann 1983). Often the bird also slowly fluttered its wings, which produced an audible sound. The birds of nest 10 consistently displayed whenever the canopy was parted for observation. Once, the incubating bird rapidly flitted from ground to raupo, a display similar to the "swanning" of Virginia Rails *(Rallus limicola)* (Kaufmann 1983). The crake held its head and neck at normal position, the back horizontally straight, the tail pointed upward, the wings held out with their edges close to the ground, and the primaries and secondaries fanned out and pointing nearly upward.

The Marsh Crake also gave a display that included wing fanning. Once, when the tussock was parted, the bird was not on the nest but gave a chirp from within the tussock. It jumped down into the open water and began to leave, but returned to the tussock, drooping the wing nearest the observer so that the wing tip touched the water. Similar Marsh Crake displays with both wings have been reported by Hobbs (1967) and Glayre & Magnenat (*in* Cramp & Simmons 1980).

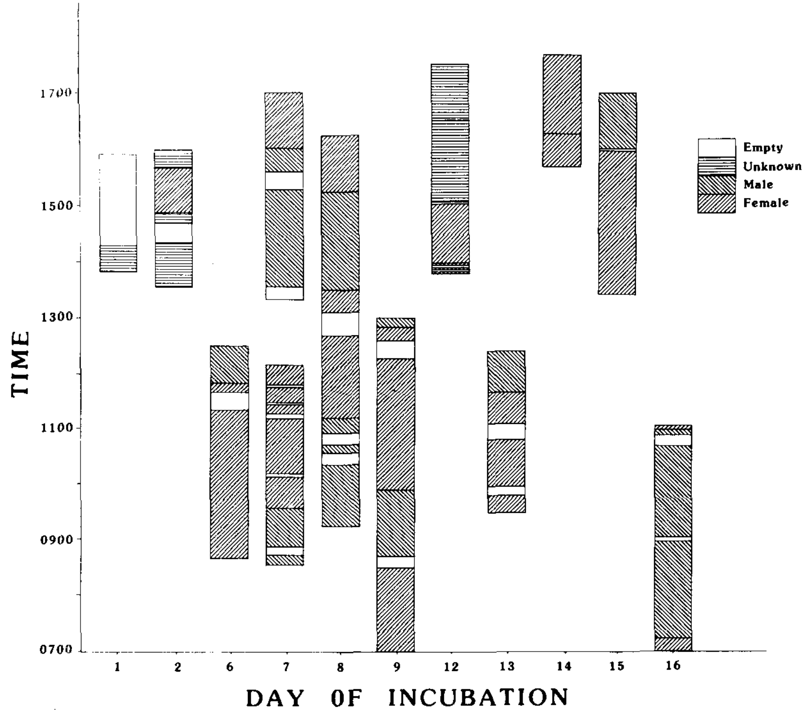

FIGURE 2 — Incubation of eggs by a pair of Spotless Crakes

Chick rearing

We are uncertain how long Spotless Crakes remain in the nest with their chicks, as they abandoned the nest when we inspected it. One brood, near the tower hide, remained on the nest for 20 hours, while heavy rain fell, before leaving when R. Lavers disturbed them. These chicks left when the nest was approached, moved to the vicinity of one of the presumptive nests a few metres nearby, and remained there for several days. Adults could be seen carrying food items back to this nest. Sixteen days after hatching the adults and chicks were seen moving from this area into the flax. The chicks were not observed with the adults again, and juveniles seen in this area later were of unknown origin.

We did not see Marsh Crakes with young.

Intraspecific competition

Direct evidence of competition between Spotless and Marsh Crakes is limited to a few observations of Spotless Crakes chasing Marsh Crakes (Howard 1962). Reactions to taped calls gave the opposite impression at Pukepuke Lagoon. Marsh Crakes actively answered taped calls of Spotless Crakes; one Marsh Crake came out on to an open mudflat and approached within 2 metres of the observer. Recordings of Marsh Crakes played at active territories of Spotless Crakes produced a few weak responses, as if they were intimidated or unstimulated.

The bill sizes and shapes of the two species are strikingly alike (Tables 4 and 5), the bill of the the Marsh Crake averaging slightly smaller. The ratios of bill sizes varied from nearly 1:1 in length to 1:1.1 in depth.

The location of museum specimens collected indicates that Spotless Crakes are more abundant in the North Island and Marsh Crakes are more abundant in the South Island. There were 11 skins of Spotless Crakes in the National Museum taken from the North Island and none recorded from the South Island. There were 5 skins of Marsh Crakes taken from the North Island and 27 skins taken from the South Island in the National and Canterbury Museums.

TABLE 4 — A comparison of bill sizes (mm) of Spotless Crakes and Marsh Crakes from Museum skins ($\bar{x}$; SD; n)

	Spotless Crake	Marsh Crake	Ratio of Spotless/ Marsh	T-test
Length	15.3- 20.6 (18.1; 1.45; 19)	15.7- 19.5 (17.8; 0.98; 36)	1.017	s.d.
Width	3.9- 6.5 (4.9; 0.81; 18)	3.7- 5.9 (4.6; 0.48; 35)	1.065	n.s.
Depth	5.9- 8.4 (7.0; 0.68; 18)	5.4- 7.7 (6.3; 0.47; 34)	1.111	s.d.

TABLE 5 — Weights (g) and lengths (mm) of exposed culmen, tarsometatarsus, and middle toe plus claw of Spotless Crakes and Marsh Crakes captured at Pukepuke Lagoon.

	Weight	Culmen	Tarso-metatarsus	Middle toe & Claw
Spotless Crake				
	$\bar{x}$ 47.5	18.2	29.9	35.7
	R 37.0-60.5	16.3-20.2	23.6-32.6	32.1-38.3
Marsh Crake				
	$\bar{x}$ 41.7	17.4	29.0	37.2
	R 40.0-46.0	15.6-18.9	26.6-30.8	34.3-39.7

DISCUSSION

Nesting

Many species of rails build more than one platform or nest some time during the breeding season. Those of the crakes appear to have been built before incubation, but other rails, such as males of Sora and Virginia Rail, build extra nests when incubation has finished. A variety of functions for such nests has been suggested for different species of rails: to synchronise the breeding cycle of the pair; to make the territory more attractive to females; to provide a substrate for copulation; to confuse and frustrate egg predators; as a second nest or a renest; for roosting by the mate not incubating or brooding part or all of the young. Until such functions have been defined for each species, perhaps a more general term such as "presumptive" nest should be used instead of using labels of presumed function.

Why most Spotless Crakes nest from mid-September to mid-October, when the early spring is cool and insect numbers are low and when they have smaller eggs and fewer eggs per clutch, will remain unknown until we know if crakes renest or have double broods. If the crakes do have two broods, they probably retain their territory through the breeding season. The first clutch would be smaller because of a lower food supply for egg production as well as brood rearing.

Field observations are inconclusive on the number of broods per year. Below the tower hide a pair began laying on 15 December 1971 in one of the presumptive nests of the first pair, whose eggs had hatched on 10 October. The male of the first pair was colour-marked with plastic leg bands, but neither bird of the second pair was marked. Perhaps the male had lost his bands, or the female had taken a new male, or the second pair was using one of the nests of the first pair. In 1982, two adjacent empty nests were found on 10 October, but on 8 December, an active nest was found nearby, indicating that the pair either was renesting or was using the territory of a pair that had finished nesting.

Intraspecific competition

Current ecological theory states that, if species require similar resources such as food or breeding sites, they are likely to compete. This competition may lead to one species excluding the other or to characters such as bill size being displaced to partition the resources. Such species exhibit a gradient of bill sizes, each successively larger species having a bill about one-third larger (Schoener 1965).

Marsh and Spotless Crakes certainly appear to violate the rules of competitive exclusion or character displacement. The bills are alike in shape and very alike in size; both probably feed on the same foods. Both nest in tussock sedge at Pukepuke. Marsh Crakes at Pukepuke responded to the taped calls of Spotless Crakes, but not vice versa, and Howard (1962) observed Spotless Crakes chasing Marsh Crakes.

One explanation could be that the two species differ subtly in breeding sites. For example, Spotless Crakes may require an overstorey of raupo or other tall emergents above the tussock sedge, whereas Marsh Crakes may require pure stands of tussock sedge. This could explain the preponderance of Spotless Crakes in the North Island and Marsh Crakes in the South Island.

Another example may be that the effect of competition between species has been exaggerated and is more complicated than formerly believed, especially in unstable environments (Weins 1983). We hope this will stimulate further study of crake competition and distribution in New Zealand.

Variation in clutch size, egg size, and hatching interval

The size of Spotless Crake clutches and size of eggs increased as the breeding season progressed. In addition, the larger clutches were more likely to hatch asynchronously. The larger size and number of eggs may simply reflect the increased availability of food and better condition of the female later in the season. However, it has been assumed that variation in clutch size, egg size, and hatching interval has adaptive value (Lack 1968, Kaufmann 1981, Slagsvold 1984). Hatching asynchrony in altricial birds is considered a brood reduction strategy. However, semi-precocial species such as those of *Porzana* require only a few days of parental feeding until the young can feed themselves. Their hatching asynchrony should be considered a mechanism of increasing brood survival. For example, Soras with larger clutches have a greater hatching interval to ensure brood survival. In North America, Sora clutches of 7-8 eggs hatched over a 2 day span, whereas clutches of 10-15 eggs hatched over 5-17 day spans.

We do not consider the long breeding season and the difference in clutch sizes to be prima facie evidence that the Spotless Crakes of New Zealand are double brooded. We hope our study will stimulate others to continue work on crakes. Our suggestions would include summer banding, when juvenile birds can be distinguished from adults, and nest research the following spring. Perhaps then the date of nesting can be associated with the age of a crake, an attempt to renest, or a second nest. We also encourage continued measurements of eggs as they are laid. We hope more data will support our observation of larger eggs in November to January. In addition, we would like to see if the smallest egg in each clutch was laid last, as a means of brood reduction.

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SHORT NOTE

Petrels nesting in the Tutamoe Range, Northland, 1916-1923

M. J. Imber (1987) has given a comprehensive account of the past and present status of the Black Petrel *(Procellaria parkinsoni)*, including the inset of his Figure 6, which shows former breeding sites of this petrel on the main islands of New Zealand.

The information in his report has brought into focus some events which I have long thought should be placed on record. Perusal of Imber's account confirmed that this information was not in the literature.

From 1916 to 1923 I lived, as a schoolboy, on a bush farm on the Tutamoe Range. My father, H. A. Olsen, was manager and part owner of this farm of 750 ha. As well as being a bush farmer, he was very interested in anything related to the bush and the wildlife in it. He had been brought up in the Seventy Mile Bush in southern Hawke's Bay, and his father, A. Olsen, was one of an enthusiastic band of amateurs, led by Henry Hill, who collected botanical specimens for Colenso in 1880-1890.

One of H. A. Olsen's jobs in running the farm was to round up cattle which had wandered into the bush. For this purpose he had two, sometimes three, dogs with him, one of which, Sandy, was an enthusiastic forager. Soon after we moved on to the farm, probably in early 1917, Sandy surprised H. A. Olsen by rushing in under a big rata *(Metrosideros robusta)* and coming out with a struggling bird which was completely new to him. He was familiar with the birds of the bush. Kaka *(Nestor meridionalis)* were then quite common in the Tutamoe Range. Red-crowned Parakeet *(Cyanoramphus novaezelandiae)* were present and, in the evening, Brown Kiwi *(Apteryx australis)* could be heard calling adjacent to the farmhouse. On one occasion, probably in 1919 or 1920, H. A. Olsen saw a pair of Kokako *(Callaeas cinerea)* to the south of the farm block in heavy bush of what is now the Kaihu State Forest. At this time Kokako were considered to have gone from Northland by about 1900 (Oliver 1955), which surmise has happily proved incorrect.

Meanwhile the identity of the birds which Sandy used to drag from under the tree roots continued to elude H. A. Olsen. Sandy would catch three to five each year; sometimes the dog would be restrained when it was realised in time what he was after, and sometimes he was unable to get at the birds because of the length of their tunnel. Almost always the birds Sandy caught were adults, and only once or twice were they obviously well-grown immature birds. H. A. Olsen employed a few regular farmhands, and in 1919 two ex-sailors came to work on the farm. When they were shown one of the birds they immediately pronounced it to be a "mollyhawk", but they were puzzled at its being in the bush. My recollection is of a strongly built bird with dark plumage; I also remember the interest shown in what appeared to us to be the complicated structure of the bill, as we compared it with the much simpler structure of the bills of bush birds.

The Tutamoe Range is actually a plateau of Miocene Basalt (Stipp & Thompson 1971), rising to 770 m at the south end in the Kaihu State Forest and extending north through the Marlborough State Forest to the southern confines of Waipoua Forest. At the locality of the nesting sites it is c. 3-4 km wide, c. 550 m a.s.l, and 14.5 km directly from the Tasman Sea. There, it presents a definite escarpment to both east and west, with the eastern side the higher of the two.

The petrel nesting area extended from the western escarpment to about 800 m further inland and ran south-west from where Opouteke Road climbs on to the plateau on the south bank of the Mangatu Stream, almost to where the Waingarara Stream leaves the plateau. During the period 1916-1923, this area was in bush which was being felled. The bush was a podocarp-hardwood complex with only two kauri *(Agathis australis)* on the whole farm block. Largely it consisted of rimu *(Dacrydium cupressinum)*, miro *(Podocarpus ferrugineus)*, rata, pukatea *(Laurelia novaezelandiae)* and toru *(Persoonia toru)*. Since 1923 I have been back only in 1965. The nesting area was then all cleared for farmland. I am told that it is now being planted in *Pinus radiata*.

The nesting colony discussed therefore no longer exists. However, to the south in Kaihu State Forest and to the north in Marlborough State Forest, identical habitat to that used in 1916-1923 by that colony still exists. It may be that petrels still nest in the Tutamoe Range.

From my reading of Falla *et al.* (1981), the three species that qualify are Sooty Shearwater *(Puffinus griseus)*, Grey-faced Petrel *(Pterodroma macroptera)* and Black Petrel. After so long, I can offer no final opinion as to which species was found by the dog. My only clue is that, in patrols of Horowhenua beaches in recent years, I have picked up specimens of Sooty Shearwater and Grey-faced Petrel. Neither species registers with me as being the same as the fairly large dark-plumaged petrel I remember from the Tutamoe Range. My presumption therefore is that these birds were Black Petrels.

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[M. J. Imber commented that the description of the habitat and habits of the petrel concerned is identical with other accounts (e.g. Buller, Dieffenbach) of Black Petrels nesting on mainland New Zealand and that, in his opinion, it was this petrel that Olsen observed, – Ed,]

SWAMP HABITAT USE BY SPOTLESS CRAKES AND MARSH CRAKES AT PUKEPUKE LAGOON

By GERALD KAUFMANN

ABSTRACT

A combination of searching for nests and responses to taped calls of Spotless Crakes *(Porzana tabuensis)* was used to determine habitat use by and abundance of Spotless Crakes and Marsh Crakes *(P. pusilla)*. Spotless Crakes preferred to nest in scattered to dense tussock sedge *(Carex secta)* with an overstorey of raupo *(Typha orientalis)*. Responses to taped calls indicated that they may have also nested in dense flax *(Phormium tenax)* and dense raupo. Limited information on Marsh Crakes indicated that they nested in tussock sedge with little or no raupo overstorey.

INTRODUCTION

Ornithologists have successfully used tape recordings with Spotless Crakes and, less successfully, Marsh Crakes for over a decade as a major surveying tool (Ogle & Cheyne 1981). However, they have not been used to study the breeding status of crakes. Most of the few nests found have been the Spotless Crake nests described by Hadden (1970, 1972) in narrow swamp streams running through hilly pastures near Hamilton. In this study, my aim was to investigate the use of swamp vegetation by crakes.

STUDY AREA AND METHODS

Pukepuke Lagoon is an 86 ha Game Management Reserve of the New Zealand Wildlife Service. It lies on the coastal sand dune country of the Manawatu. The vegetation, climate, and history of Pukepuke Lagoon have been described by Ogden & Caithness (1982). The dominant emergent macrophytes of the lagoon are raupo *(Typha orientalis)*, flax *(Phormium)*, tussock sedge *(Carex secta)*, and cabbage tree *(Cordyline australis)* (see Fig. 1).

Observations were made from 13 September to 28 December 1982. At first, I tried to search all the vegetation types for nests with equal intensity, but areas of lodged raupo and of flax proved impossible to search. Later searches concentrated on areas of tussock sedge and raupo of low to medium density.

Taped calls of Spotless Crakes were played, slightly louder than normal for the birds, for 6.5 minutes at each of 45 stations about the lagoon. I approached the stations by walking on pathways about the swamp and by rowing in the lagoon, along the swamp edge. Tapes were played in the morning at stations 1-31 and at stations 32-45 usually in the evening but occasionally in the morning. Tapes were played on the least windy day in each 7-10 day period between 14 September and 14 December 1982, 13 times altogether.

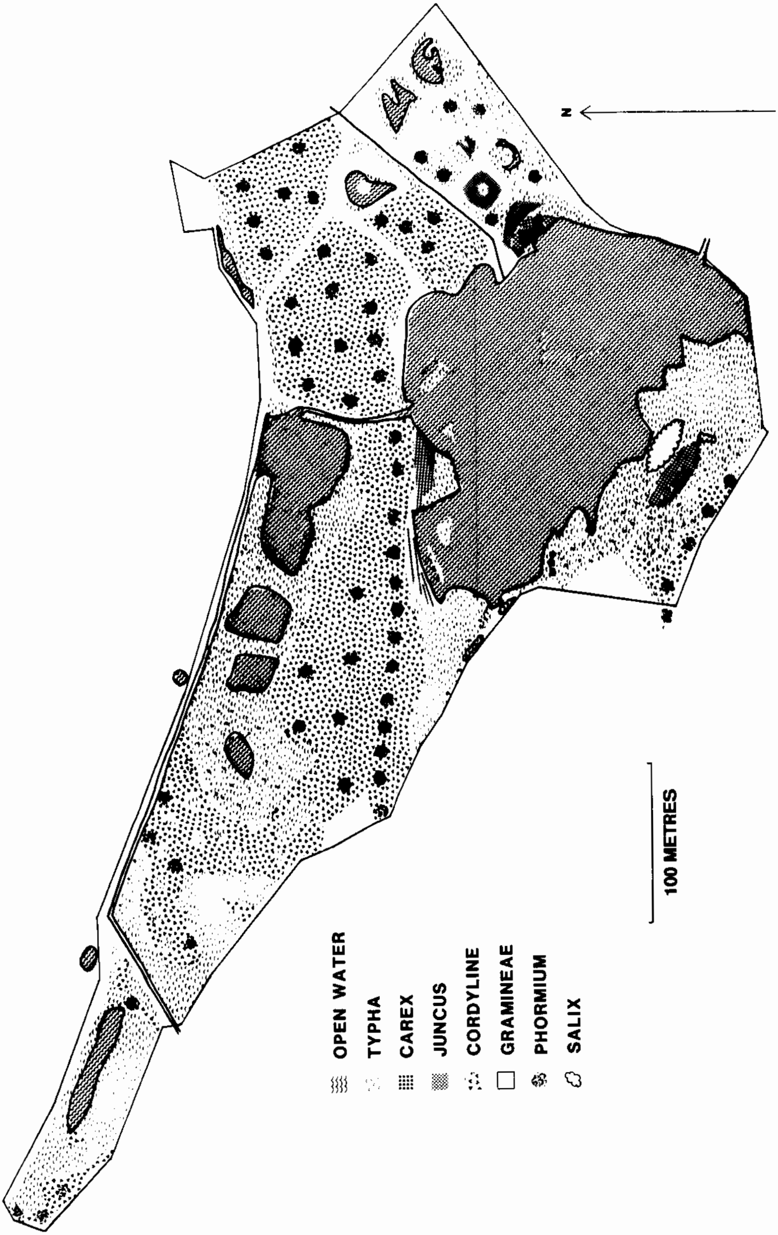

FIGURE 1 — Dominant macrophyte vegetation of Pukepuke Lagoon

RESULTS

Nests

Figure 2 shows the locations of seven Spotless Crake nests (five active, two predated), and two Marsh Crake nests (one active, one deserted). I also found 35 empty nests singly or in groups – 15 were solitary, 7 in groups of two and two in groups of three. In addition, two active Spotless Crake nests had one empty nest nearby and a third had two empty nests nearby. Groups of nests were presumed to have been made by a single pair. Empty nests I presumed had been constructed by Spotless Crakes because they had responded nearby and because they were more abundant than Marsh Crakes.

Active and empty nests of both species were in tussock sedge. The nest bowl was made of sedge, although several nests incorporated a few pieces of raupo and one a piece of wireweed *(Polygonum aviculare)*. The sedge plants used were usually shaped like a haystack, with the pedestal well covered by overhanging tillers of previous years. The nest was usually placed loosely in old tillers near the pedestal. Several nests in very dense raupo were located in the crown of less robust sedge plants.

All Spotless Crake nests were in sedges with an overstorey of raupo, often just beyond the edge of a pure stand of sedge. (See Fig. 3.) Pure stands of sedge seemed to be avoided. The density of the sedge did not seeem to be important. Areas of medium-density raupo and very scattered sedge, e.g. between stations 5 and 8, had about as many nests as did the areas of very dense sedge, e.g. between stations 8 and 10. However, more nests may have been in dense sedge stands, where my nest searching was less efficient. In the areas of scattered sedge nearly every suitably shaped sedge had a nest.

The two Marsh Crake nests were in isolated tussock sedges. The active nest was so surrounded by water that the pair walked along a single route across floating stalks, which required short hops and swims. (See Fig. 4.) The vegetation surrounding the second nest was sparse, consisting of two sedges and scattered stubble.

Reactions of Spotless Crakes to broadcast calls

I broadcast calls from stations along the approachable swamp edge. These were close enough for the calls to overlap slightly, and thus I could sample the swamp thoroughly. I cannot just state the dominant vegetation and crake responses at each station because the vegetation was so mixed and the crakes moved so much in response to the call. Spotless Crakes often walked 15-20 metres toward the broadcast station. In general, raupo was the dominant vegetation sampled and most crake responses came from raupo (see Fig. 5 and Table 1). Spotless Crakes frequently responded from some areas of dense, lodged raupo (e.g. no. 12 and 13) but rarely from other dense areas (e.g. no. 14, 15, 24, 25, and 26). Spotless Crakes did not respond from small isolated stands of raupo (e.g. no. 3, 5, 27, 30, and 35) and rarely responded from long strips of raupo (e.g. no. 2, 14, 15, 31, and 32). The greatest number of responses came from station 7, which was between two territories on a boardwalk into raupo containing tussock sedge. Most of the stations along the edge of the lagoon produced few responses, although usually where I was able to enter narrow inlets, I received more Spotless Crake (no. 39) or Marsh Crake (no. 42) responses. No calls were heard in dry raupo (no. 27 and 28).

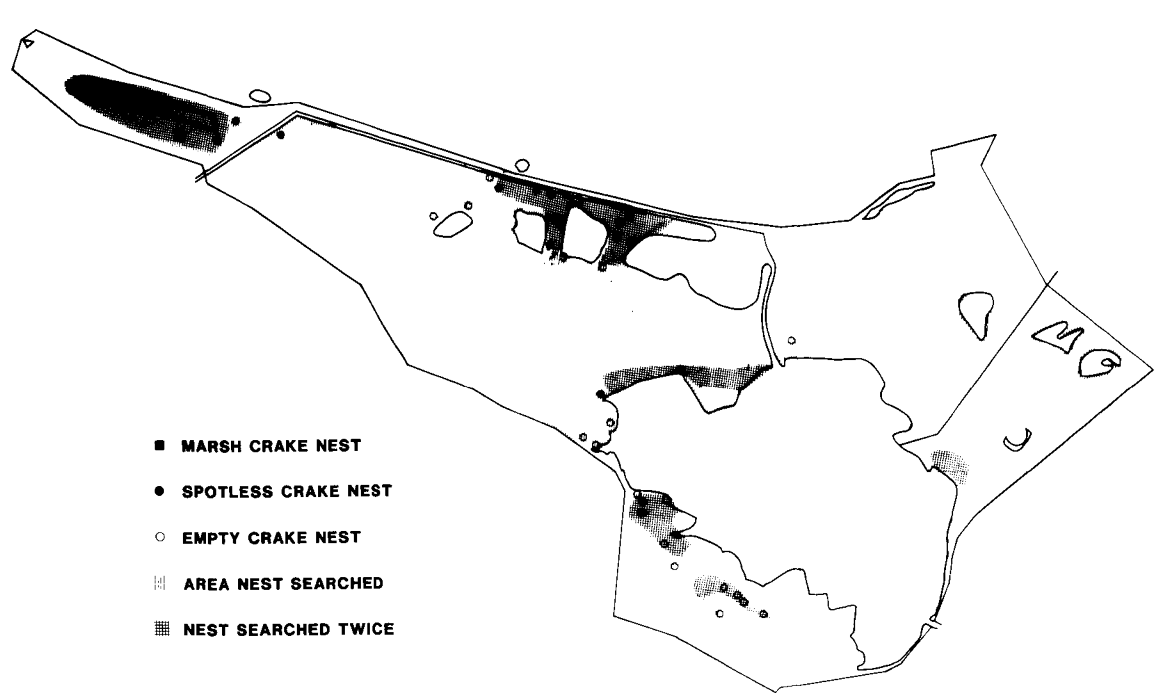

FIGURE 2 — Locations of Marsh Crake nests, Spotless Crake nests and empty nests found at Pukepuke Lagoon. Groups of nests are displayed as one.

FIGURE 3 — Tussock sedge, with dense raupo overstorey, containing a Spotless Crake nest

FIGURE 4 — Isolated tussock sedge containing a Marsh Crake nest. A sheath of tillers was removed in order to observe the nest.

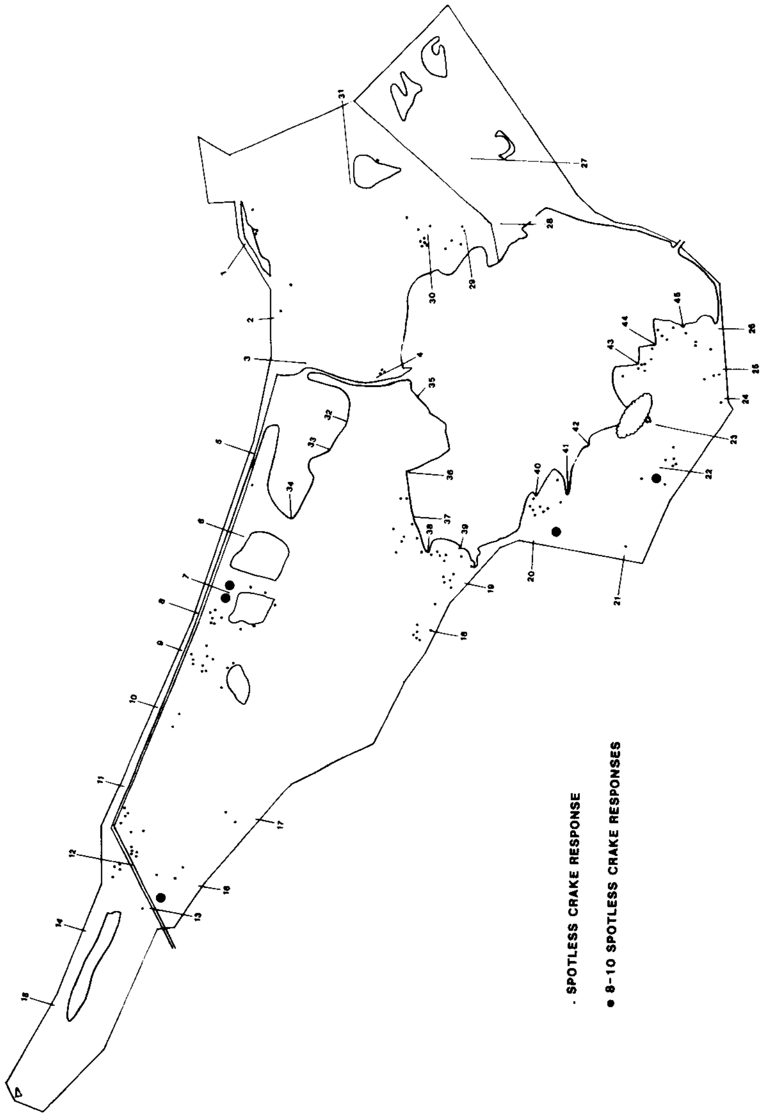

FIGURE 5. Location of Spotless Crake responses to playing a 6.5 minute tape of Spotless Crake calls at 45 stations

TABLE 1 — Number of Spotless Crakes responding to taped calls per station

STATION NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
14-18 SEP	1						3		1			1	1										
23-24 SEP	1	1					3	1				1	1					1	1	1		2	2
29-30 SEP	1						1	2	1A		1	1	2						1			2	1
6-8 OCT	1			1			2	1A	1	1	1	1	1		1	1		1	1	1		2	1
15 OCT				1			1	1	2		1						1	1	1	1		1	2A
21 OCT							2	1A				1	1						1	2		2	
27 OCT							1	1A	1			1	1A						1	1	1		
8 NOV				1			1	1A	1		1	1	1				1	2	2	1		1	1A
16 NOV				1								1	1									1	1A
30 NOV												1	1									1	1A
1 DEC					1		2		1		1	2	1										
9 DEC		1					2		1		1	1	2									1	1
14 DEC							3		2	1	1							2					

STATION NO.	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	TOTAL CRAKES
14-18 SEP										1			1	1		1		1					13
23-24 SEP		1	1			2	1				1					2				1			23
29-30 SEP			1			1	1				3			1	1	1				1		1	
6-8 OCT		1					1				1	2		1	1			1				1	26-27
15 OCT							2								1	2							17-18
21 OCT	1						1	1		1	3			1			2	2	2	2	3	1	32-33
27 OCT						1	1				1									1	1		11-13
8 NOV																							12-14
16 NOV															1				1	1			7-8
30 NOV																							
1 DEC					1				1														11
9 DEC		1																		1			13
14 DEC												1								1			12

A - Possibly same crake as heard at previous station

Few responses were received from flax/cabbage tree associations with a wet mud floor (no. 2, 3, 4, and 38). One of the two responses at station 2 was from a crake that had followed the recorder from the raupo area of station 1; I believe the responses at station 4 came from a narrow band of raupo which had a nest behind it. Most striking was the complete lack of calls from the flax/cabbage tree area at station 10 because I received a large number of responses at adjoining stations on both sides (no. 7-9, 11-13). The two calls heard at station 10 came from adjacent raupo, as did the only call heard at station 21. The young flax/tussock sedge area between stations 22 and 23 was also avoided by the crakes which responded there. R. Lavers (pers. comm.) had observed crakes nesting there in 1971 before the experimental removal of raupo and subsequent growth of flax. Yet crakes did not completely avoid flax. Stations 29 and 30 were on a boardwalk through a flax/cabbage tree/raupo association with a few centimetres of water. Spotless Crakes responded from both areas, particularly from the wetter station 30.

No responses were received from the isolated solid stand of tussock sedge near station 28. The crakes which responded from the long strip of tussock sedge between stations 36 and 38 began their calling from the flax, cabbage tree or raupo stand behind the sedge and came toward the recorder.

Reactions of Marsh Crakes to broadcast calls

Marsh Crakes responded to tapes of Spotless Crakes at stations 15 (one 30 September) and 40 (one 17 September, two 8 October, one 21 October). The Marsh Crake which responded on 21 October came out of the vegetation on to a mudflat. I then played a 5-minute tape of Marsh Crake calls. The bird flew behind me and responded vigorously and continuously. I could not find a nest near station 40 but believe that a pair nested nearby. I did find a Marsh Crake nest near the area it called from by station 15. On 25 October I played the Marsh Crake tape at Stations 5 to 15 and 18 to 23. At least two (possibly five) Spotless Crakes responded weakly at the cessation of the Marsh Crake tape recording. They appeared unstimulated, if not intimidated, by the Marsh Crake calls. No response was given to the Marsh Crake tapes played on the dark calm evening of 22 September (stations 5-8) or 26 October (stations 35-41).

Number of territories

The number of territories along the tape-playing route can be estimated from the Spotless Crake responses. Using the location of calls and the usual behaviour of several weeks of vigorous calling followed by silence or weak calling, I estimated 13 probable and 19 possible territories. Those stations which received 5-9 crake responses on 4-7 occasions were regarded as possible territories. Those stations receiving at least four consecutive vigorous responses from the same area were regarded as probable territories. (See Fig. 5 and Table 1.)

DISCUSSION

Spotless Crakes seem to need large continuous blocks of tall emergent plants with an understorey of sedge for nesting. The tall plants are raupo at Pukepuke Lagoon, but are willow (*Salix* spp.), manuka (*Baumea* spp.), and cabbage tree in the Whangamarino wetlands (Ogle & Cheyne 1981). These trees may be less suitable than raupo because the crakes at Whangamarino apparently had larger territories than at Pukepuke Lagoon, as evidenced by the greater distance they walked toward the tape recorder. The sedges used as nest sites were *Carex secta* at Pukepuke Lagoon, and probably at Whangamarino, but were *C. lessonia* in the Waingaro district (Hadden 1970, 1972; Ogle & Cheyne 1981). Many smaller stands of emergents not used in the spring were frequented by crakes in the autumn (A. Grant, pers. comm.).

The crakes favoured nesting in large, unbroken stands of emergents, a preference similar to the Sora and Virginia Rails in the United States (Kaufmann 1971). When the stands were opened, the Sora and Virginia Rail numbers were reduced by more than the simple number of territories lost. Similar results with crake numbers may occur if stands are opened in waterfowl management. Many areas of Pukepuke Marsh were sprayed with Round Up in February to control raupo growth. The effects of spraying were not evident during October but regrowth did not occur in November. Stations 5-13, 16, 18, 19, 23, 33-37, and 42-44 were slightly affected by a lack of small to moderate raupo regrowth. The "rice bowl" area near stations 14 and 15 and the triangle between stations 24, 26, and 45 were most affected. By late November, these raupo stands began to fall down and were moderately open by December. Livestock trampling may have similar effects. When I played tapes of Spotless Crakes along the north side of nearby Omanuka Lagoon, I heard only one response from a small fenced portion inaccessible to livestock.

Active crake management would require the protection of existing tussock sedge and the encouragement of new sedge stands. In 1982, many sedges were dying, probably from shading and nutrient competition by raupo or flax and possibly from prolonged inundation. Raupo has become more important in plant competition and swamp eutrophication than in the past because of its pronounced response to phosphate fertilisers (Ogden & Caithness 1982). Hand or chemical control of dense raupo could be attempted, but with caution because the sedge is vulnerable to a second spraying of Round Up by helicopter. If shading is the main factor that affects the sedge, raupo duff could be burned off, again with caution. *Schoenus nigricans*, a tussock sedge of the British Isles, is intolerant of weeds growing on its pedestal, and fires increased the number of such weeds (Dawkins 1937).

Manipulation of water levels may be a useful tool for managing rail habitat, especially sedge. Costello (1936) found tussock forms of *C. stricta* to be adapted to fluctuating water levels and described both mesic and xeric adaptations. However, prolonged high water levels weaken or kill tussock sedge as well as encourage *Typha* growth (J. Zimmerman, pers. comm.). Thus the prolonged water levels described for waterfowl nesting, brood rearing, and hunting may not be compatible with long-term sedge survival. In addition, the seeds of the flax growing high on sedge pedestals or crowns more likely floated there. Low water levels at the time of flax seed dispersal could, at least temporarily, slow the spread of seed. In 1982, the spread and growth of flax on sedge crowns was rapid. Nearly every sedge in the pool between stations 22 and 23 had 1-2 flax plants in its crown or pedestal; in 1971 none was present (R. Lavers, pers. comm.).

Few solid recommendations can be made for germinating and growing new stands of tussock sedge. Little autecological work has been done since the classical studies of Costello (1936) and Dawkins (1937). Most *Carex* species require a 3-12 month after-ripening period; light and artificial abrasion of the seed testa increases germination (Jermy *et al.* 1982). Costello believed that *C. stricta* spread primarily by rhizomes, whereas Dawkins believed that *S. nigricans* spread by seed. It might be noted that Costello studied undisturbed wetlands, whereas Dawkins studied areas of secondary succession where the peat had been previously removed. Both found that tussock sedge grew best where water levels were at ground level and that the highest pedestals were formed in deeper water. Costello noted rapid initial growth from rhizomes in the deeper water but that older sedges did not change over 6 years. He believed that sedges persist 60-80 years.

I would guess that the tussock sedges at Pukepuke Lagoon in 1982 had germinated during the 1910-1930 period of extensive drainage. The exposed bottom caused rapid nutrient release from the decomposing peat, and chemical changes caused by the oxidation of previously reduced compounds. After germination at the edge of the lake, the water levels remained low for several years, permitting the sedge to establish. Spring rains temporarily inundated the sedge and stimulated pedestal growth. Sand continued to blow and block the lagoon drainage, slowly raising the water level, stimulating the pedestal formation seen today. S. Shailer (pers. comm.) believes that the same sedges present today, especially the two in front of his maimai, were present in 1942. If this sequence is correct, management for tussock sedge requires several years of drawdown followed by slowly increasing water levels.

The swamplands of the central United States vary greatly from year to year in their conditions of cover and water, caused by periodic wet-dry weather cycles and explosion-crash population cycles of muskrats (Weller & Spatcher 1965). Wetland species of birds have adapted to this natural instability of their habitat by yearly and long-term population shifts (Weller 1979, 1980). Greater species diversity occurs when clusters of wetlands of diverse seral stages are present. Weller recommended that, for wetland management, wetlands purchased should be in the form of such clusters of swamps, including the upland between them. Such recommendations apply to New Zealand as well, even though the swamplands are more stable and have fewer species than those of North America. The purchase of a cluster should reduce the need for intensive management if the requirements of all swamp species are present and would reduce the need to take risks by experimenting with management techniques.

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NOTES ON THE BIRDS, REPTILES AND MAMMALS OF TONGATAPU AND 'EUA (TONGA)

By B. J. GILL

ABSTRACT

During 13 days on Tongatapu and 9 days on 'Eua (Kingdom of Tonga) I noted 16 and 20 species of birds respectively. I collected 5 species of reptile on Tongatapu and 3 on 'Eua. Two species of ectoparasite from a Polynesian Rat *(Rattus exulans)* were identified.

INTRODUCTION

In 1986 I spent 3 weeks in Tonga, comprising 13 days on Tongatapu (4-7 and 17-25 October) and 9 days on nearby 'Eua (8-16 October). Both islands were widely traversed – on foot, by bicycle, by vehicle or on horseback. Little has been published on the natural history of these islands and so it seems worthwhile recording details of the birds, reptiles and mammals that I saw. As this paper was going to press a very full account of the birds of 'Eua by Rinke (1987) appeared, based on observations from March 1983 to September 1984. The most recent account of the birds of Tongatapu seems to be that of Dhondt (1976) from observations in March and April 1974.

Tongatapu (260 km^2) is more-or-less flat and densely populated. Nearly all the original forest cover has long since given way to coconut plantations and other forms of agriculture. 'Eua (90 km^2), 20 km south-east of Tongatapu, rises to 300 m above sea level. The flatter western side is mainly cultivated but the hills and cliffs to the east have large tracts of rainforest.

BIRDS

No time was spent at sea, and so the following list is biased towards land and shore birds. No birds were examined closely or critically enough to determine their race.

The terrestrial avifauna of Tonga is limited in diversity, but all the species I recorded on Tongatapu and 'Eua were common. On 'Eua there are no small bush birds to exploit the rainforest understorey. Bird-watching from the forest floor is therefore rather unrewarding. The parrots and pigeons of greatest interest usually frequent the canopy and are difficult to approach and see clearly. Femaeaki Lookout on a cliff east of Kahana Spring, north-east of Houma, is excellent for bird-watching because it overlooks the canopy of forest growing at a lower level. I had better sightings of pigeons in 5 minutes at Femaeaki than I had elsewhere on 'Eua in as many days.

TAVAKE (WHITE-TAILED TROPICBIRD) *Phaethon lepturus*
Tongatapu. Not noted.
'Eua. Widespread at the coast and flying overhead inland.

NGUTULEI (BROWN BOOBY) *Sula leucogaster*

Tongatapu. Not noted.

'Eua. Seen at sea from cliffs at southern end.

HELEKOSI (FRIGATEBIRD) *Fregata* sp.

Frigatebirds were not seen closely enough to determine the species.

Tongatapu. One at Ha'atafu Beach.

'Eua. A few soaring high over centre of island. Seen from cliffs at southern end.

CRESTED TERN *Sterna bergii*

Tongatapu. Three roosting and fishing at end of peninsula east of Nuku'alofa.

'Eua. Not noted.

GREY NODDY *Procelsterna cerulea*

Tongatapu. Not noted.

'Eua. Seen from Femaeaki Lookout (north-east of Houma) and from cliffs at southern end.

NGONGO (NODDY) *Anous* sp.

Noddies were not seen closely enough to determine the species.

Tongatapu. Two on reef at Keleti Beach.

'Eua. Two on reef at 'Ufilei Beach (north of 'Ohonua). Seen from cliffs at southern end.

'EKIAKI (WHITE TERN) *Gygis alba*

Tongatapu. One at Ha'atafu Beach.

'Eua. Widespread in ones or twos. Perching in forest trees at 'Ufilei Beach (near 'Ohonua). Seen inland, even in the central hills, flying overhead.

KIU (LEAST GOLDEN PLOVER) *Pluvialis fulva*

Most birds were in intermediate plumage, with some evidence of black patches on the breast.

Tongatapu. Common on mudflats along Nuku'alofa waterfront and at Christianity Landing Place; singly or in pairs, well spaced out. Some seen feeding among roots of tall mangroves near Mu'a were very well camouflaged. On mown grass at Fua'amotu Airport.

'Eua. One flying along reef at 'Ufilei Beach (near 'Ohonua). Tufuvai – one at a small rocky pool on the otherwise sandy beach. On grazed grass at Hango Agricultural College (near 'Ohonua) and near cliffs at southern end. Thirty-six sleeping or foraging on mown grass at Kaufana Airstrip on 17 October.

KIU (WANDERING TATTLER) *Tringa incana*

Tongatapu. Common in small numbers along Nuku'alofa waterfront. Two on rocky reef at Keleti Beach.

'Eua. One darting at food between waves breaking over rocky reef along rugged shore on north-eastern tip (map series X872, sheet 23, 167 439). Several near 'Ohonua Wharf feeding among low woody plants growing on the rocky foreshore. Tufuvai – one at a small rocky pool on the otherwise sandy beach.

TURNSTONE *Arenaria interpres*

Tongatapu. Two on mudflats at Christianity Landing Place (7 October).

'Eua. Not noted.

MOTUKU (REEF HERON) *Egretta sacra*
Total sightings for both islands together were six dark phase and two white phase.
Tongatapu. A few on mudflats along Nuku'alofa waterfront and at Christianity Landing Place. One on rocky reef at Keleti Beach.
'Eua. A few on reef at 'Ufilei Beach and between there and 'Ohonua.

MOAKAIVAO (FERAL DOMESTIC FOWL) *Gallus gallus*
Tongatapu. Not noted in a truly feral state.
'Eua. Heard crowing in heavy bush leading down to rocky shore at north-eastern tip (map series X872, sheet 23, 167 439).

VEKA (BANDED RAIL) *Rallus philippensis*
Tongatapu. Not noted.
'Eua. Seen five times at roadsides both inland and near the coast; frequenting plantations, heavy bush and low shoreline scrub.

DOMESTIC PIGEON *Columba livia*
Tongatapu. Seen only in Nuku'alofa, along the waterfront, at the vegetable market and in the Royal Palace grounds. Some birds brown and white. Probably not truly feral to date.
'Eua. Not noted.

LUPE (PACIFIC PIGEON) *Ducula pacifica*
Tongatapu. Not noted.
'Eua. Widespread and common in or near forest; occasionally in cultivated areas. Difficult to approach closely. They fly strongly, covering long distances, and sometimes perform acrobatic flights like New Zealand Pigeons *(Hemiphaga)*.

KULUKULU (CRIMSON-CROWNED FRUIT-DOVE) *Ptilinopus porphyraceus*
I recorded fruit-doves at 10 locations. At only two of these could I approach birds closely enough to see the yellow undertail coverts that distinguish this species from the similar Manuma'a or Many-coloured Fruit-dove *(Pt. perousii)*. I assumed all fruit-doves to be Crimson-crowned, perhaps wrongly.
Tongatapu. Not noted.
'Eua. Widespread and common in or near forest; occasionally in cultivated areas or scrub. Difficult to approach closely; more often heard than seen. They fly strongly, covering long distances.

KAKĀ (RED-BREASTED MUSK PARROT) *Prosopeia tabuensis*
Tongatapu. Not noted.
'Eua. Widespread and common in and about thick forest from the shoreline to the summit. Present at 'Ufilei Beach and in the Lakataha Ravine near 'Ohonua. Seen at Ha'aluma Beach in old coconut plantations with dense understorey scrub.

PEKEPEKA (WHITE-RUMPED SWIFTLET) *Collocalia spodiopygia*
Tongatapu. Common in all habitats. At 'Anahulu Cave near Haveluliku on 24 October dozens of birds were sitting on nests attached to the roof. The site is now operated as a commercial tourist attraction. Electric lights are switched on periodically, but the cave is very large and remains dim. The birds seem unaffected but more detailed observations

of the effects are needed. Constant clicking sounds (for echolocation) were given by dozens of birds in flight within the cave.

'Eua. Common everywhere.

SIKOTĀ (WHITE-COLLARED KINGFISHER) *Halcyon chloris*

Tongatapu. Not greatly abundant. Seen at Ha'atafu Beach and just outside Nuku'alofa.

'Eua. Common everywhere.

MANUFO'OU (RED-VENTED BULBUL) *Pycnonotus cafer*

Tongatapu. Common everywhere.

'Eua. Not noted.

NGUTUENGA (EUROPEAN STARLING) *Sturnus vulgaris*

Tongatapu. Widespread but not particularly common.

'Eua. Small numbers at Hango Agricultural College (near 'Ohonua). Flock of 20-30 on grassy areas near cliffs at southern end.

MISI (POLYNESIAN STARLING) *Aplonis tabuensis*

Tongatapu. Seen in Nuku'alofa.

'Eua. Widespread and common, particularly in or near forest. Several collected nest material; one nest site was a hollow branch of a dead tree in partly cleared forest. A bird seen closely had a dark iris.

SIKIVIU (POLYNESIAN TRILLER) *Lalage maculosa*

Tongatapu. Common everywhere. Apparent immatures seen on 5 October.

'Eua. Common everywhere.

FULEHEU (WATTLED HONEYEATER) *Foulehaio carunculata*

Tongatapu. Common everywhere.

'Eua. Common everywhere.

REPTILES

I collected six species of reptiles, five from Tongatapu and three from 'Eua. All specimens are held in Auckland Museum and the registration numbers are cited here. Besides these species, on 12 October I saw clearly, but could not catch, a large brown skink more than 80 mm from snout to vent. It was in coastal scrub between 'Ohonua and 'Ufilei Beach ('Eua) and had a striped pattern across its "lips". It was active in the heat of the day, though in shade, and moved very rapidly among the exposed roots of a tree.

The Tongan name for gecko is *moko* and for skink is *pili*. Some locals mentioned the name *fokai*. H. L. Bregulla established that this refers to the iguana *Brachylophus fasciatus* (W. Pond, pers. comm.).

STUMP-TOED GECKO *Gehyra mutilata*

Tongatapu. Found as a house gecko in Nuku'alofa (H1017, H1018).

'Eua. Not noted.

OCEANIC GECKO *Gehyra oceanica*

Tongatapu. Not noted.

'Eua. Two collected under bark of rotting trees – H1015 in forest north-east of Houma and H1016 in partly cleared forest in the central hills near the summit. H1015 had a fresh weight with intact tail of 12.5 g.

MOURNFUL GECKO *Lepidodactylus lugubris*

Tongatapu. Found as a house gecko in Nuku'alofa (H1021).

'Eua. Found as a house gecko at Hango Agricultural College near 'Ohonua (H1019, H1020).

SNAKE-EYED SKINK *Cryptoblepharus poecilopleurus*

Tongatapu. One collected at Keleti Beach in low supralittoral vegetation (H1013).

'Eua. Not noted.

BLUE-TAILED SKINK *Emoia cyanura*

Tongatapu. Seen in litter and low vegetation at Good Samaritan, Keleti and 'Anahulu Beaches (H1010-1012).

'Eua. Very common and widespread. In shoreline litter and vegetation, litter under intact and partly cleared forest and in open grassy areas. They reach high densities, far greater than I saw on Tongatapu, perhaps because there is less predation on 'Eua by Domestic Fowls (H999-1009).

MOTH SKINK *Lipinia noctua*

Tongatapu. One collected at Keleti Beach in low supralittoral vegetation (H1014).

'Eua. Not noted.

MAMMALS

PEKA (FLYING FOX) *Pteropus tonganus*

Tongatapu. Large colonies roosted by day in trees at Tofoa (near Nuku'alofa) and Kolovai.

'Eua. A few flying after dark among trees at 'Ufilei Beach. Several seen from Femaeaki Lookout roosting in the forest canopy below.

KUMĀ (POLYNESIAN RAT) *Rattus exulans*

Tongatapu. Not noted.

'Eua. A juvenile (Auck. Mus. M458), found injured on a track through a plantation north-east of Houma, had as ectoparasites the flea *Xenopsylla vexabilis* and the louse *Hoplopleura pacifica* (R. L .C. Pilgrim, pers. comm.).

DISCUSSION

My observations on the general status and distribution of birds agree closely with those of Dhondt (1976) and Rinke (1987). Rinke (1987) confirmed that Many-coloured Fruit-doves *(Ptilinopus perousii)* occur on 'Eua. I did not see the Blue-crowned Lory or Henga *(Vini australis)* on either island. It was reported from both by duPont (1976), but according to Rinke (1986) it is now extinct on these and certain other Tongan islands. The Spotless Crake or Moho *(Porzana tabuensis)* and Fiji Shrikebill or Fuiva *(Clytorhynchus vitiensis)* also appear to have disappeared from 'Eua within the last century, except that the shrikebill persists on Kalau, the islet southwest of 'Eua (Rinke 1987).

Watling (1978) cited an unpublished MS by E. Carlson (1974) as authority for stating that Red-vented Bulbuls occur on 'Eua, having spread there from Tongatapu where introduced in the 1940s. My observation, however, and that of Rinke (1987) is that the species is currently absent from 'Eua. European Starlings are said by Rinke (1987) to be a very recent arrival on 'Eua. He did not note them at the grassy areas near the southern cliffs, and so they are likely to have spread there since 1984.

Watling's map (1982: 103) indicates that Tonga lies in a region where Polynesian Starlings have yellow irides, the iris being brown in the main Fiji islands to the west. This is wrong. The bird I saw closely had a dark iris, and all those seen by Rinke (1987) had brown irides.

Very little has been published on the reptiles of Tonga. According to Rinke (1987) 'Eua has "about 11 species of reptiles", including an endemic *(Lepidodactylus euaensis)*, but he gave no further details and cited no published references. Gibbons (1985) reported *Lepidodactylus manni* from 'Eua, this having previously been considered endemic to Viti Levu, Fiji group. The species I noted are widely distributed in the south-west Pacific and are likely to occur on both islands when I recorded them from only one. The iguana *Brachylophus fasciatus* is said to occur on both Tongatapu and 'Eua (Gibbons 1981). Rinke (1986) believed that it can still be found on Tongatapu but he did not find it on 'Eua. I saw none. The large skink *Tachygia* (or *Eugongylus) microlepis* is known only from the two types collected on Tongatapu last century (Greer 1974). Rinke (1986) did not find this species. There is a slight possibility that this was the large brown skink I saw on 'Eua but could not catch.

It was depressing on 'Eua to see slash and burn agricultural practices encroaching on rainforest when there is so much guava scrub that might be cleared instead. The proposal for a national park on 'Eua (e.g. Singh 1986) needs encouragement.

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SHORT NOTE

Co-operative breeding in Brown Creeper?

In co-operative breeding, more than two adults assist in rearing young (Elmen 1984). The closely related Yellowhead *(Mohoua ochrocephala)* and Whitehead *(M. albicilla)* are known to breed co-operatively (Soper 1976, Gill & McLean 1986, G. Elliott pers. comm.). However, no evidence of co-operative breeding was found by Cunningham (1985, pers. comm.) in the only detailed breeding study of Brown Creeper *(Finschia novaeseelandiae)* made to date. Here, we report observations made at Kowhai Bush, Kaikoura (where Cunningham also worked) of Brown Creepers appearing to breed co-operatively.

Brown Creepers had a poor breeding season in 1986-87 at Kowhai Bush, probably because of a drought, which killed about 10% of the trees in the study area and partly defoliated many others. Of about 25 pairs studied only four (possibly five) fledged chicks, several built nests but did not lay, and many apparently did not start nest-building. Thus, a large number of birds were presumably physiologically ready to breed but did not do so.

On 5 November, when we removed chicks from a nest for banding, three adult Brown Creepers arrived and mobbed us. On 16 November, we mist-netted the adults from this nest one day after the (banded) chicks first flew. While we were holding the parents for banding, we saw two other adult creepers with the chicks, which were perched 10 m away, and heard the usual calls of chicks being fed. On their release, the true parents (determined by many subsequent checks of band combinations) flew immediately to the chicks and chased the other birds away.

On 11 November we saw three adult creepers within two metres of a nest containing banded young. One of these adults was chased off by the other two. Two adults from this nest were banded on 19 November. After 19 November, an unbanded bird was twice seen feeding the chicks while the banded birds (the usual feeders) were away. On two other occasions an unbanded bird approached with food and was chased off. Two unbanded creepers were often seen within 20 m of these chicks after they had left the nest. Any other creepers which approached to within a few metres of the chicks were always chased by the banded adults if they were seen.

Do these observations show that Brown Creepers are co-operative breeders?

If co-operation is indeed rare in Brown Creepers, then our observation of co-operation in two of the three families we followed intensively seems too coincidental. However, Cunningham (1985) did not see similar behaviour despite many hours of observation. The most likely explanation is that the drought in the study area in 1986-87 resulted in frustrated breeders showing "parenting" behaviour which was appropriate to the time (breeding season), but not to the place (neighbour's nest or chicks). The observations of true parents consistently chasing off other birds bringing food supports this view. The argument, which is developed in detail in Jamieson (1986), suggests that Brown Creepers should not yet be regarded as co-operative breeders.

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NOTICE

Ecology Division DSIR Bibliography 1946-1986

This 72-page indexed bibliography lists 810 items and covers the 40 years of published work of Ecology Division, DSIR. The main fields of study include the ecology of New Zealand land mammals (particularly the role of introduced mammals in New Zealand ecosystems) and birds (including agricultural pests). There are also papers on New Zealand lizards, invertebrates, vegetation studies, the ecology of many offshore islands, and others of a more general nature. From 1969 to 1982 the Division was also active in freshwater research, and a number of papers deal with this topic.

The Bibliography costs $10 and can be ordered from the Publications Officer, Ecology Division, DSIR, Private Bag, Lower Hutt. Please make cheques payable to Ecology Division, DSIR.

TRAPPING BROWN TEAL: A COMPARISON OF METHODS

By GRANT DUMBELL

ABSTRACT

Over 27 months, 335 Brown Teal were trapped and banded on Great Barrier Island. Four trapping methods were used to trap both solitary and flocking birds in all seasons. The efficiency of the trapping methods is compared, and the study areas and banding scheme are described. The computer program used to generate the colour band combinations is included as an appendix.

INTRODUCTION

The trapping and marking of individuals is an essential consideration in most biological field studies. Trapping methods should efficiently and repeatedly catch study animals, minimise stress and injury, and not selectively sample the unmarked population. These affect the interpretation of results and are problems with all single trapping methods, but using an array of methods can reduce the bias.

Capturing individuals allows morphometric, sex, age and condition data to be collected and provides an opportunity for collecting parasitic and faecal samples. When released, marked animals can be followed through space and time for estimates of many population parameters (Seber 1973).

Four methods were used to make 404 captures of Brown Teal *(Anas aucklandica chlorotis)* on Great Barrier Island (36°11′ S, 175°25′ E). The effectiveness of these methods is compared and the study areas and colour banding scheme are described.

STUDY AREAS AND METHODS

Study areas

The four study areas (Figure 1), all on the east coast of Great Barrier Island, are known Brown Teal roost sites (Ogle 1980). They were chosen for their positions in separate watersheds and for their north-south spread along the island's major axis.

The Awana Valley has large low-lying flats, crossed by shallow drains. It is drained by the tidal Awana Stream which, combined with the large, steep catchment area, promotes flooding at any time of year. The flats are mostly in pasture, with extensive areas of *Juncus* (mainly *J. sarophorus*) and *Cyperus ustulatus*. A large area of lupins *(Lupinus arboreus)* lies behind the beach while scattered clumps of manuka *(Leptospermum scoparium)*, kanuka *(Kunzia ericoides)* and larger trees occur throughout the valley. The streamside vegetation varies from grass to kanuka but is predominantly an association of *Cyperus*, *Juncus*, *Plagianthus divaricatus* and manuka. Some flax *(Phormium tenax)* occurs and a few pohutukawa *(Metrosideros excelsa)* trees are present.

The Whangapoua study area is in the Okiwi basin, a large watershed characterised by an extensive estuarine harbour. The Whangapoua Creek drains the south-eastern part of the basin, which is mostly pasture. It is fringed with kanuka, puriri *(Vitex lucens)*, totara *(Podocarpus totara)*, and kowhai *(Sophora microphylla)*, before running through manuka, *Olearia solandri* and flax scrub, which has a *Juncus* and *Cyperus* understorey. The creek then flows through rush (mainly *Juncus maritimus*), sedge *(Baumea juncea)* and mangrove *(Avicennia resinifera)* zones surrounding the estuary. It is also tidal and can flood heavily.

The Saltwater study area is at the southern end of Medland's Valley. Here the tidal Saltwater Creek is often blocked by a sandbar during summer. Shallow drains cross the largely *Juncus* and *Cyperus* covered flats, and the stream runs along the eastern edge of them with *Juncus* or manuka/kanuka right to the water in most places. Thicker vegetation on the grass areas of stream bank is being promoted by recent fencing.

Harataonga is a small grassy valley surrounded by regenerating manuka. Two tidal streams meet behind the sand dunes, both with little bankside vegetation, other than grass.

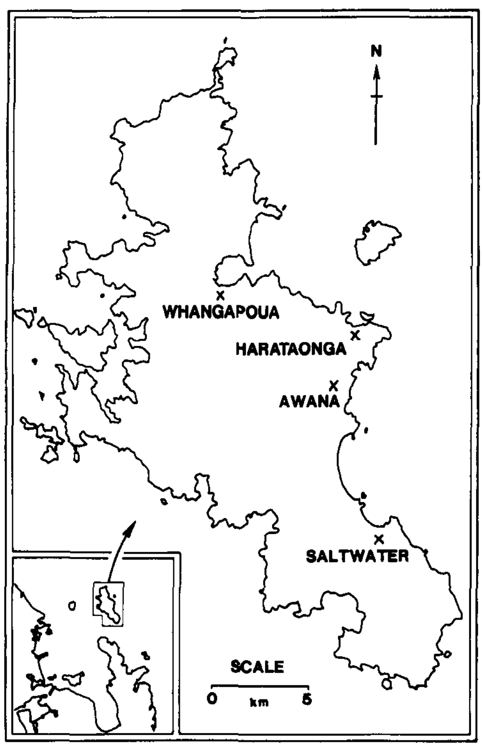

FIGURE 1 — The location of each study area on Great Barrier Island

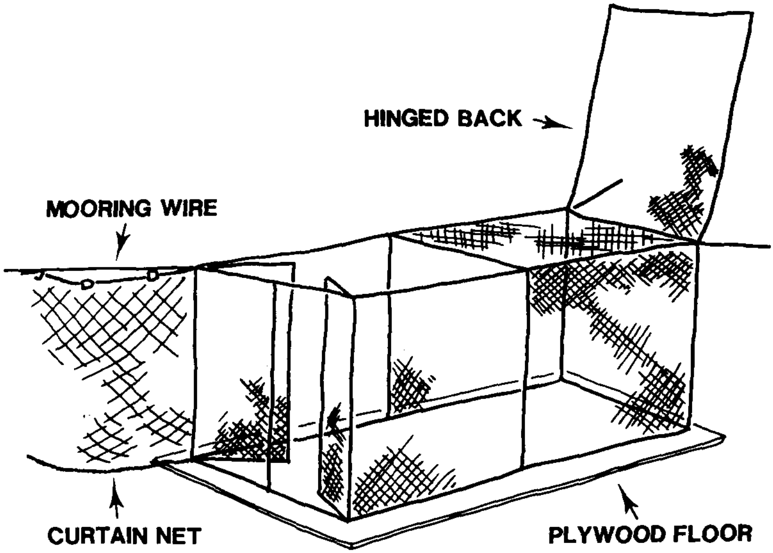

FIGURE 2 — A cage trap with curtain nets in place and back hinged open

Trapping

The main trapping method used a cage (1 m x 1 m x 2 m) moored midstream, with curtain nets angled from the doors to the banks (Figure 2). A plywood floor provided flotation while the sides, top, back and doors were steel frames covered with wire netting. The cage was moored to two taut diagonal wires crossing the stream from bank to bank. These wires also supported the curtain nets, which formed a funnel in front of the cage.

The trap was sited near the birds' roost site. Once on the water, Brown Teal will not leave it, except to take flight, and were driven into the trap by walking slowly along the bank. Trapping attempts were made when the trap floor was flooded with c.200 mm of water.

The birds were familiarised with the trap by removing the back and driving them through it the day before a trapping attempt so that they would recognise it as a thoroughfare. They found their own way back past the cage once the curtain nets were pulled away from the banks.

Next day the curtain nets were restored, the back put in place, and the two overlapping swing doors were set to leave an opening c.200 mm wide. This width opening prevented teal inside the cage from swimming out while others were swimming in. The doors were closed by a nylon monofilament run away from the trap for c.100 m. When as many birds as possible had entered the cage, a pull on the line closed the doors. A vertical steel bar acted as a doorstop and prevented the doors from bursting outward. The doors were then tied shut, the cage was released from its mooring wires and curtain nets, and moved to the bank, where the birds were transferred to bags before banding. To prevent the cage from sinking while it was being moved to the bank, a safety wire was passed through the cage and over one mooring wire.

The second trapping method was to handnet birds feeding at night on the pasture. Birds were spotlighted and caught in a wire netting handnet with a 2 m long handle and a 1 m diameter hoop attached to the end. This pinned the bird to the ground, preventing it from thrashing around and becoming entangled, as it would in a conventional net.

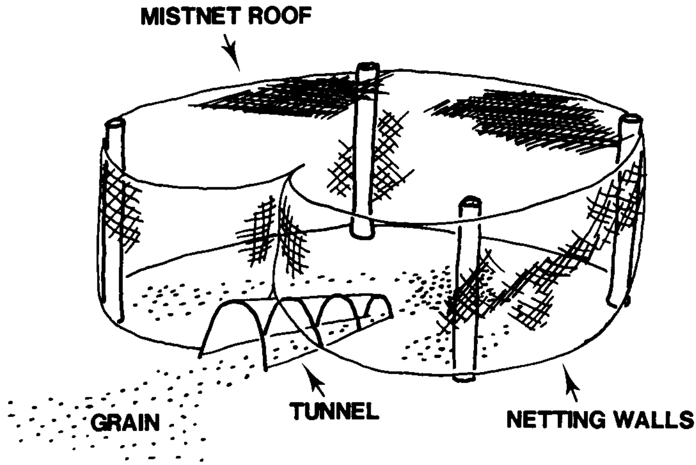

FIGURE 3 — The lilypad trap set for a trapping attempt

The third method was to use a lilypad trap constructed of wire netting walls with a mistnet roof (Figure 3). The near-circular walls enclosed an area c.2 m in diameter and were attached to stakes for rigidity. From where the netting ends were joined a 1 m long wire tunnel protruded into the centre of the trap. It had a 200 mm square entrance that narrowed to 100 m square at the exit. Light steel arches strengthened it and anchored it to the ground.

A trail of wheat led birds into the trap. It began clear of the tunnel entrance, and led to concentrations of grain away from the tunnel exit. Once inside, birds followed the circular walls around and climbed over the tunnel, unable to relocate the narrow opening through which they had entered. The trap was set before dark and cleared at dawn.

For several nights before the trap was set, the trapsite was pre-baited. The trap was gradually built over several days as the birds became used to feeding near the wire netting. Trapping was discontinued in bad weather so as not to hold the birds overnight and prevent them from feeding.

The fourth trapping method was opportunistic. Brown Teal nest very secretively, and the fastest way to find nests was to use a muzzled pointing dog. Birds were often found roosting in thick vegetation, and most were captured by hand. Where possible, sitting females were also captured.

Banding

The basis of each band combination was an L-sized stainless steel band (Cossee & Robertson 1982) on the left leg of females and on the right leg of males. The colour band position above the metal band designated the study area in which the bird had been banded. The metal band was then wrapped in reflective Scotchlite tape of the same colour so that it appeared as a colour band and could be seen at night. The double colour on one leg meant birds could be assigned to a subgroup of the banded population if the full combination could not be read. In combinations where no colour band appeared above the metal band, the metal band was wrapped in silver tape. As the metal band was heavier than the plastic colour band, the metal band was never placed above a colour band.

Each bird's second leg carried one or two colour bands. These formed a unique combination for each site colour and were repeated for each site. They were never formed by two bands of the same colour, which would have led to confusion with the double-colour site code on the other leg.

The bird's short legs prevented the use of standard 10 mm colour bands, and so all colour bands were moulded from 7 mm strips of Darvic plastic. They had an internal diameter of 10 mm with two and a half wraps and could not slip over or inside the 11 mm metal band. Band migration was further reduced by winding colour bands on the bird's leg in opposing directions. The colours used were blue, green, lime, orange, red, white and yellow, while the Scotchlite tape colours used were green, red, silver, white and yellow. Black bands were not used as they did not contrast sufficiently with the bird's slate-grey legs.

A total of 784 colour combinations was available within the limits of this banding scheme and the complete list of combinations was generated by a BASIC computer program. This program (Appendix) is easily modified to suit the boundary conditions of other banding schemes.

RESULTS

Between November 1984 and January 1987, 404 captures were made for 335 birds to be banded, including two birds that had been banded in October 1976. The cage traps allowed a large number of birds to be banded quickly, and was achieved when 90 birds were banded in 5 days, including 34 in one trapping attempt. This method (Table 1) made 220 captures (55%). However, it suffers from trap shyness as the birds learn to avoid the trapsite.

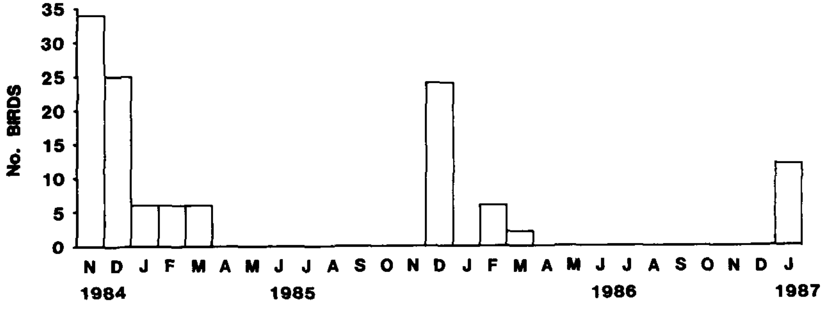

FIGURE 4 — Histogram showing the highest number of birds cage trapped each month

The highest number of birds caught each month, in any trapping attempt (Figure 4), declined rapidly each summer. Trapping success was initially high in 1985/86 but dropped more rapidly, and to a lower level, than in 1984/85. Likewise, the initial trapping success each year declined, because of experienced birds in the flock.

By spotlighting and handnetting, trapping was continued after the birds had begun to avoid the cage traps. Experienced birds again learnt to avoid being trapped, by avoiding the spotlight, and this problem is reflected in the low rate of recaptures for these two methods (Table 2).

The major value of the lilypad trap is its ability to retrap birds, and 61% of all recaptures were made in it. This is 3.5 times higher than any other method. It has also yielded the most multiple recaptures (Table 2). Trap avoidance is much less of a problem as 36% of the 42 recaptures were on successive nights while 57% were within three nights. Although this trap does not catch large numbers of birds, it does consistently catch birds, unlike the cage traps.

TABLE 1 — A breakdown of captures from each study area and each trapping method

	TRAPPING METHOD				
STUDY AREA	Cage Trap	Handnet	Lilypad	Dogs	Total
Awana	66	71	73	34	244
Whangapoua	77	0	0	0	77
Saltwater	77	0	0	2	79
Harataonga	0	0	0	4	4
TOTAL	220	71	73	40	404

TABLE 2 — A dissection of the total captures from each trapping method

	TRAPPING METHOD				
	Cage Trap	Handnet	Lilypad	Dogs	Total
Total Captures	220	71	73	40	404
No. First Captures	213	59	31	32	335
No. Recaptures	7	12	42	8	69
% Recaptures	3.2	16.9	57.5	20.0	17.1
No. Multiple Recaptures	0	1	19	3	23
% Multiple Captures	0	1.5	26.0	7.5	5.8
Sex Ratio F:M	1.1:1	1.2:1	0:4.1	1.9:1	1:1

During winter, the birds disperse from the roost to breed. Using dogs is the only practical method of capturing birds during this time, although it is time consuming and yields fewer captures. The recapture rate is, however, comparable to the rate for the cage traps and handnet.

The Lilypad trap is the only method that has captured a biased sex ratio (Table 2, $X^2 = 8.39$, $p < 0.05$). However, the overall sex ratio, for all 404 captures, does not differ significantly from 1:1 ($X^2 = 0.02$, $p > 0.05$), which is consistent with regular counts of both males and females at the Awana roost site.

None of the 65 recaptures was made outside the study area in which the first capture was made. This includes the two 1976 birds, which were not considered as recaptures for this study.

DISCUSSION

Leg bands were the only form of marking used. Nasal saddles (Patterson 1978) were rejected as birds with nasal saddles may survive less well than birds without nasal saddles (T. Caithness, pers. comm.). Patagial tags (Patterson 1978) were also rejected because they can be preened into the birds' plumage, making them unreadable. These alternative marking methods are useful when birds have their legs obscured, but leg band combinations can be accurately read on Brown Teal even when they are swimming.

These trapping methods efficiently, repeatedly, and without injury captured birds in all seasons. No resighted or recaptured bird had shed its metal band, but because colour band loss has been recorded, interpreting the resightings of birds that had only one of a possible two bands forming the combination is a problem. A bird having only one band may have been banded with one band or have lost one of its original two bands. This possible misidentification argues for the exclusion of single 1-1 band combinations, which would result in 14% fewer combinations in this banding scheme. This could be recovered by using an eighth colour.

Scotchlite tape (Carrick & Murray 1970) is not widely used. Its main advantage is to turn the metal band into a colour band, which could be very useful in banding schemes restricted by a limited range of colours, as with Saddlebacks (*Philesturnus carunculatus*, T. Lovegrove, pers. comm.) and Bellbirds (*Anthornis melanura*, J. Craig, pers. comm.). It can also be used to convert unicolour bands into bicolour bands. No resighted or recaptured bird showed any sign of losing its tape. To guard against abrasion the tape encircled the metal band twice. If the upper layer wore off, the lower layer still showed the colour. Although the tape must be removed to read the metal band, this small inconvenience is outweighed by the advantages.

The main advantage of the appended computer program is that it can be run on a home computer, unlike other published programs (Buckley & Hancock 1968). While this guarantees an error-free list of band combinations, it does not prevent the error of using combinations more than once. This leads to ambiguous identifications, and affected 3% of birds banded in this study.

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APPENDIX

This program is essentially three nested counting loops. Each loop is reset to zero after it has used all available band codes, which are the initial of each colour. With eight band codes, each loop counts in base eight. Each combination has four positions, one of which is reserved for the metal band. This invariant position (M) is used to terminate and reset each loop. The other three positions are for colour bands. The first (F) position is opposite the metal band and below the second (S) position. The third (T) position is above the metal band and is the site colour. The S and T positions can be vacant, and so a blank band code is introduced in line 30. However, if a band is always required in the S position, the S counter in lines 10 and 210 must be set to one. If a band is also required above the metal band, the T counter in line 10 must also be set to one. The combination counter (C) is included so that the number of combinations generated can be checked against any permutation calculations done. If other colours are used, the array (lines 20 to 110) must be altered, and if further positions are required, further loops can be inserted and the printing instructions (lines 150, 160) expanded. Twelve REM statements are included to help with program dissection. These can be deleted for programming economy.

```
5   REM COUNTERS SET TO ZERO
10  C=0:F=0:S=0:T=0:M=8
15  REM DIMENSION ARRAY FOR COLOUR CODES
20  DIM B$(8)
25  REM SETTING COLOUR CODES AS ARRAY ELEMENTS
30  B$(0)=" "
40  B$(1)="B"
50  B$(2)="G"
60  B$(3)="L"
70  B$(4)="O"
80  B$(5)="R"
90  B$(6)="W"
100 B$(7)="Y"
110 B$(8)="M"
115 REM FIRST BAND POSITION COUNTER
120 F=F+1
125 REM ILLEGAL COMBINATION CHECKS
130 IF F=M THEN 180
140 IF F=S THEN 120
145 REM PRINTING COLOUR COMBINATION
150 ? B$(T);B$(M);"-";B$(S);B$(F),
160 ? B$(S);B$(F);"-";B$(T):B$(M)
165 REM COMBINATION COUNTER
170 C=C+2:GOTO 120
175 REM SECOND BAND POSITION COUNTER
180 S=S+1:IF S=M THEN 200
185 REM RESET FIRST BAND POSITION COUNTER
190 F=0:GOTO 120
195 REM THIRD BAND POSITION COUNTER
200 T=T+1:IF T=M THEN 220
205 REM RESET SECOND BAND POSITION COUNTER
210 S=0:GOTO 190
215 REM TOTAL COMBINATION MESSAGE
220 ?
230 ? "THERE ARE ";C;" INDIVIDUAL"
240 ? "COMBINATIONS AVAILABLE"
250 END
```

SHORT NOTE

Red-crowned Parakeet on Burgess Island

The Red-crowned Parakeet *(Cyanoramphus novaezelandiae)* is common on Hauraki Gulf islands that are free of ship rat *(Rattus rattus)* and Norway rat *(R. norvegicus)*. These islands have a wide range of vegetation – grassland, coastal scrub, and coastal forest. Little Barrier also has inland softwood and hardwood forests.

The feeding and nesting habits of the Red-crowned Parakeet were studied on Burgess Island, in the Mokohinau Islands, during a visit by the Offshore Island Research Group from 27 December 1983 to 4 January 1984.

Most of Burgess Island is covered in rank buffalo grass *(Stenotaphrum secundatum)*, other grasses, various herbs and bracken. Coastal forest and scrub remnants are confined to the cliffs.

Burgess Island does not appear to have been permanently occupied in pre-European times (Esler 1978). A lighthouse began operation in 1883 and the lighthouse keepers farmed the island until 1980, when the light was automated. Cattle, sheep and goats were kept on the island and farming reduced the native vegetation to a few scattered remnants on the cliffs and largely destroyed the island's natural flora and fauna.

Forest regeneration seems to be quite slow. Areas free of stock in 1957 (Gillam 1960) and 1978 (Esler 1978) show only minor changes in vegetation. Regeneration may be inhibited by the low rainfall (700-750 mm/year), salt spray and the smothering effect of buffalo grass.

Red-crowned Parakeets nested and roosted around the coastal cliffs, particularly where there were overhanging pohutukawa trees. They ranged over the whole island during the day, being easy to follow and observe, and occasionally they flew to the adjacent Knights Islets.

Parakeet feeding was observed with 8x35 binoculars. I recorded activities at 1 minute intervals throughout the day, often following birds to make feeding observations in a range of vegetation types. I recorded activity in and around three nests.

RESULTS

Feeding: Parakeets were seen to feed on a wide range of fruit, seeds and herbage (Table 1). The major components of their diet were ngaio and taupata fruit, pohutukawa flowers, flax seed and grass seed. Fruit and seed together formed over two-thirds of the diet.

Nesting: The three nests found were on steep faces on the coastal cliffs. Two nests were in dense herbaceous vegetation, under the roots of pohutukawa trees. I could not see whether the nests were in the vegetation or in rock crevices beneath the vegetation. The third nest was in a rock crevice on a rock face partly covered in pohutukawa trees.

At all three nests birds spent long periods of up to 3 hours on the nest. Often both birds were on the nest, particularly in the afternoons. In the mornings the birds made more frequent forays out from the nest to feed.

TABLE 1 — Red-crowned Parakeet summer diet on Burgess Island

		Observations	%
Fruit:	Ngaio (*Myoporum laetum*)	53	20.1
	Taupata (*Coprosma repens*)	29	11.0
	Pohuehue (*Muehlenbeckia complexa*)	7	2.7
	- (*Coprosma macrocarpa*)	5	1.9
	Total fruit	94	35.6
Seed:	*Flax (*Phormium tenax*)	32	12.1
	Unidentified grass	13	4.9
	- (Cyperus ustulatus)	12	4.5
	*Catsear (*Hypochoeris radicata*)	12	4.5
	- (*Chionochloa bromoides*)	11	4.2
	Sweet vernal (Anthoxanthum odoratum)	9	3.4
	Yorkshire fog (*Holcus lanatus*)	5	1.8
	Buffalo grass (*Stenotaphrum secundatum*)	2	0.8
	Total seed	96	36.4
Flowers:	Pohutukawa (*Metrosideros excelsa*)	56	21.2
Herbage:	Lichen (Ramalina celastri)	8	3.0
	Iceplant (Disphyma australe)	3	1.1
	Mercury Bay weed (*Dichondra repens*)	3	1.1
	Ngaio leaves	2	0.8
	Iceplant (*Aptenia cordifolia*)	1	0.4
	Wiwi (*Scirpoides nodosum*) culms	1	0.4
	Total Herbage	18	6.8
Total Observations		264	

* Seed and Seed Capsule

The birds were highly selective for certain food items. Fruit and *Cyperus* and *Chinochloa* seeds are relatively scarce on the island but made up 40% of the diet.

Grass seed was abundant during the time of our visit but made up only 17% of the diet. The most common grass, buffalo grass, was less than 1% of the diet.

Almost 85% of the parakeets' diet was native plant species, which cover less than 35% of the island. Most of the native vegetation on Burgess Island is coastal herbfield and low scrub.

DISCUSSION

There was no significant difference in summer foraging of Red-crowned Parakeets (Fig. 1) between my observations on Burgess Island and Dawe's observations (1979) on Tiritiri Matangi Island ($X^2 = 1.018$, $P > 0.05$, df = 5). Both islands have large areas of grassland and small remnant patches of native trees and shrubs.

Pohutukawa flowers were less important on Tiritiri Matangi, where kanuka *(Kunzia ericoides)*, pohuehue, *Solanum*, *Sonchus* and inkweed

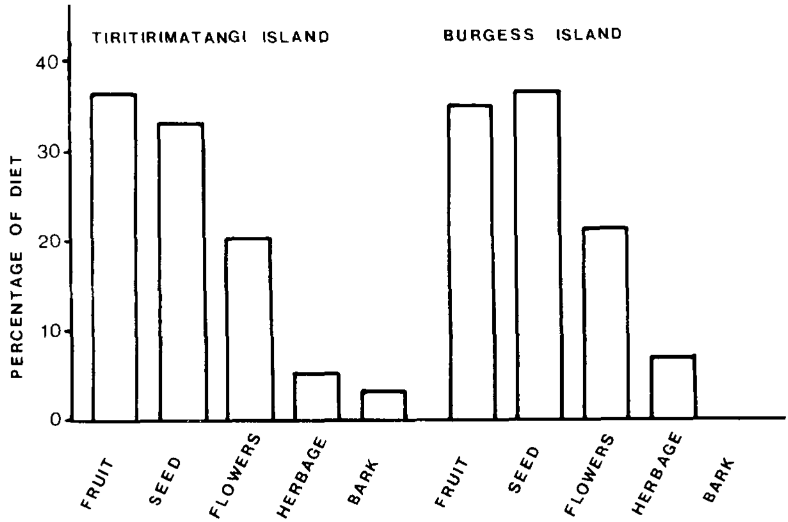

FIGURE 1 — A comparison of Red-crowned Parakeet summer diet on Tiritiri Matangi Island and Burgess Island

(Phytolacca octandra) flowers were also taken. This may reflect the impoverished flora on Burgess and the lack of flowers, other than pohutukawa, at the time of our visit. Major differences in flowering times precluded similar comparisons with Little Barrier Island (Dawe 1979).

Although fewer food species are available on Burgess Island, the proportions of food items taken are similar to those on Tiritiri Matangi Island. The forest and shrubland provide a major part of the parakeets' diet in summer and further regeneration on both islands can only enhance their numbers.

The scrub-covered islands of the Hauraki Gulf have a high number of succulent fruiting shrubs. They may provide habitats equal to those of more forested islands, such as Little Barrier Island, for Red-crowned Parakeet.

Nesting: As there are no trees with suitable nesting cavities on Burgess Island, the parakeets seem to be using the only suitable alternative – vegetation and crevices on the the coastal cliffs.

ACKNOWLEDGEMENTS

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SEABIRDS FOUND DEAD ON NEW ZEALAND BEACHES IN 1985, AND A REVIEW OF *PTERODROMA* SPECIES RECOVERIES SINCE 1960

By R. G. POWLESLAND

ABSTRACT

In 1985, 5967 kilometres of coast were patrolled and 28,304 dead seabirds were found, both new records for the Beach Patrol Scheme. A new species for the Scheme was a White-bellied Storm Petrel *(Fregetta grallaria)*. Ten species were found in greater numbers in 1985 than in any previous year: Little Blue Penguin *(Eudyptula minor)*, Buller's Mollymawk *(Diomedea bulleri)*, White-headed Petrel *(Pterodroma lessonii)*, Fairy Prion *(Pachyptila turtur)*, Fulmar Prion *(P. crassirostris)*, Fluttering Shearwater *(Puffinus gavia)*, Australasian Gannet *(Sula bassana)*, Pied Shag *(Phalacrocorax varius)*, Red-billed Gull *(Larus novaehollandiae scopulinus)* and White-fronted Tern *(Sterna striata)*. The record numbers of Fairy Prions, Fulmar Prions and Fluttering Shearwaters were the result of wrecks of these species in August-September, mainly along the western and southern coasts of the North Island.

A summary is given of the coastal and monthly distributions for most *Pterodroma* species found during the 1960-1984 period. The most frequently found species was the White-headed Petrel, a result of 50-100 being found in spring of most years.

INTRODUCTION

This paper records the results of the Ornithological Society of New Zealand's Beach Patrol Scheme for 1985. All sections were patrolled except Fiordland. Westland is not included in Table 1; patrols there were done in March (4 km), August (6 km) and October (6 km), two Fairy Prions and one White-fronted Tern being found. Some beaches on the Chatham Islands were patrolled, the results being given under the heading Outlying Islands. In total, 847 Beach Patrol Cards and 8 Specimen Record Crads were submitted.

Kilometres "travelled" are the total lengths of coast patrolled; kilometres "covered" are the lengths of coast patrolled monthly. Hence, if 1 km of beach is patrolled twice in one month, 2 km have been travelled but only 1 km covered per month.

The nomenclature used is that of Kinsky (1970, 1980), except that I have followed that suggested by Imber (1985a) for the Kerguelen Petrel *(Lugensa brevirostris)*.

RESULTS AND DISCUSSION

In 1985, several records were established, including the total distance of coast travelled (5967 km) and the number of seabirds found dead (28,304). The previous highest totals were 5600 km travelled in 1978 and 24,747 seabirds found in 1974. The number of members of the Ornithological Society of New Zealand and their friends that did the patrols in 1985 was 287, and they found 5.56 birds per kilometre of coast covered (Table 1).

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This rate of finding dead seabirds is surpassed only by the 1974 (8.5) and 1975 (5.8) results. Table 1 also gives the kilometres covered and the number of seabirds found per month and in total for the various coasts, plus the number of birds picked up per kilometre covered for each coast. Table 2

TABLE 1 — Numbers of dead seabirds recovered and kilometres covered on each coast in 1985

COAST	CODE		MONTH												TOTAL		BIRDS/KM /COAST
			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	KM	BIRDS	
AUCKLAND WEST	AW	KM	186	176	184	187	222	207	225	227	309	231	235	236	2625		
		BIRDS	403	219	603	621	500	351	801	1262	10477	1324	2365	1300		20226	7.71
TARANAKI	TA	KM	26	9	15	2	17	26	32	65	42	20	68	24	346		
		BIRDS	73	12	5	-	10	22	118	161	78	44	76	73		672	1.94
WELLINGTON WEST	WW	KM	30	20	41	19	40	9	59	69	67	35	47	4	440		
		BIRDS	131	161	131	21	99	8	227	182	123	92	188	6		1369	3.11
AUCKLAND EAST	AE	KM	64	42	36	50	32	23	36	69	58	47	101	30	588		
		BIRDS	311	336	171	68	87	13	28	319	222	311	1353	253		3472	5.90
BAY OF PLENTY	BP	KM	2	22	25	12	13	21	51	46	30	19	40	29	310		
		BIRDS	16	52	98	28	17	9	83	154	86	54	307	136		1040	3.35
EAST COAST NI	EC	KM	-	11	6	12	6	15	17	19	6	15	9	8	124		
		BIRDS	-	6	5	13	4	10	34	23	-	10	5	29		139	1.12
WAIRARAPA	WA	KM	6	4	-	-	6	7	-	18	-	2	1	5	49		
		BIRDS	2	2	-	-	3	11	-	74	-	3	2	1		96	2.00
WELLINGTON SOUTH	WS	KM	-	-	4	2	40	-	19	86	10	-	19	-	180		
		BIRDS	-	-	8	1	100	-	87	325	6	-	83	-		610	3.39
NORTH COAST SI	NC	KM	-	-	15	-	-	46	-	-	-	-	-	21	82		
		BIRDS	-	-	5	-	-	42	-	-	-	-	-	54		101	1.23
CANTERBURY NORTH	CN	KM	-	5	5	6	6	8	8	6	6	-	6	6	62		
		BIRDS	-	9	10	3	3	1	5	1	18	-	11	15		76	1.23
CANTERBURY SOUTH	CS	KM	6	8	10	8	8	8	9	35	9	8	8	-	117		
		BIRDS	7	13	25	9	17	14	6	86	15	9	7	-		208	1.78
OTAGO	OT	KM	2	7	16	10	16	16	7	6	6	10	7	8	111		
		BIRDS	2	6	22	14	49	8	2	-	2	4	6	6		121	1.09
SOUTHLAND	SD	KM	4	-	8	4	1	1	-	-	14	-	-	-	32		
		BIRDS	2	-	71	1	1	1	-	-	85	-	-	-		161	5.03
OUTLYING ISLANDS	OI	KM	2	1	-	-	-	-	-	-	-	4	-	-	7		
		BIRDS	3	3	-	-	-	-	-	-	-	2	-	-		8	1.14
TOTAL KILOMETRES TRAVELLED			360	356	484	408	486	460	507	842	646	414	588	400	5951		
TOTAL KILOMETRES COVERED			328	305	365	312	407	387	463	646	557	391	541	371	5073		
TOTAL SEABIRDS RECOVERED			950	819	1154	779	890	490	1391	2587	11112	1853	4403	1873		28301	
BIRDS/KM COVERED/MONTH			2.90	2.69	3.16	2.50	2.19	1.27	3.00	4.00	19.95	4.74	8.14	5.05			5.58

gives the coastal and monthly distributions of the less commonly found seabirds (1-20 birds in 1985), and Tables 3 and 4 give these for the more commonly found seabirds.

Unusual finds

A new species for the Beach Patrol Scheme is the White-bellied Storm Petrel, a specimen of which was found on Piha Beach (AW) in May (Table 2). Two other beach-wrecked White-bellied Storm Petrels have been found

TABLE 2 — Seabirds of which 1 to 20 specimens were found in 1985

SPECIES OR SUBSPECIES	NUMBER FOUND	COAST(S)	MONTH(S)
Megadyptes antipodes	3	CS(2), OT.	JUL, SEP, NOV.
Eudyptula minor albosignata	9	CN(3), CS(5), NC.	FEB, APR(2), JUN, AUG(3), DEC(2).
Eudyptes pachyrhynchus	1	SD.	MAR.
sclateri	1	CS.	JUL.
Diomedea exulans	10	AW(5), AE, WS(3), EC.	FEB, MAY, JUN, JUL(3), AUG(2), NOV, DEC.
epomophora	7	AW, TA, WS(5).	MAY(6), NOV.
melanophrys	9	AW(4), BP(2), EC, WW, OI.	MAY(2), JUN(2), JUL, AUG, OCT(2), NOV.
chlororhynchos	1	AE.	AUG.
cauta subspp.*	6	AW(5), EC.	JUN, JUL(2), SEP, OCT(2).
Phoebetria palpebrata	10	AW(4), AE(3), TA, WS(2).	JAN, AUG(4), SEP(3), OCT(2).
Thalassoica antarctica	2	AW, WW.	SEP(2).
Pterodroma pycrofti	1	AE.	APR.
leucoptera	2	AW, TA.	JAN, DEC.
nigripennis	3	AW, AE, CS.	MAR, MAY, NOV.
Procellaria cinerea	8	AW(5), AE, BP, WW.	JAN, FEB(3), MAR, JUL, SEP, NOV.
parkinsoni	20	AE(20).	FEB, APR, NOV(18).
westlandica	3	AW(2), WW.	JAN, SEP, DEC.
aequinoctialis	8	AW(4), AE, BP(2), WW.	JAN(4), MAR, NOV(2), DEC.
Puffinus puffinus	1	WW.	JAN.
gavia/huttoni	1	WW.	AUG.
Garrodia nereis	2	WS(2).	AUG(2).
Fregetta grallaria	1	AW.	MAY.
Phaethon lepturus	1	AE.	DEC.
Phalacrocorax spp.*	4	AW(3), AE.	JAN, JUN, JUL, AUG.
carbo	18	AW(5), AE(2), TA(3), BP, WW(4), NC, CN, OT.	APR, MAY, JUN(2), JUL(4), AUG(3), SEP(4), OCT, DEC(2).
sulcirostris	4	EC, WW, WA, WS.	MAY(2), AUG, DEC.
brevirostris	9	AW(4), AE(3), TA, NC.	JAN, MAY, JUN(2), JUL, AUG(2), NOV(2).
Leucocarbo carunculatus chalconotus	6	OT(4), SD(2).	MAR(3), MAY, JUN, NOV.
Stictocarbo punctatus feathersoni	1	OI.	FEB.
Stercorarius spp.*	1	AW.	MAR.
skua lonnbergi	4	AW, WS(2), SD.	JUL, AUG, SEP(2).
longicaudus	1	WW.	JUL.
Larus spp.*	2	OT(2).	MAR(2).
bulleri	20	EC(6), CS(4), OT(9), SD.	JAN, FEB(3), MAR(10), MAY(2), JUN(4).
Hydroprogne caspia	17	AW(14), AE(2), TA.	JAN(2), MAR, JUN(3), JUL, AUG(4), SEP(3), OCT(3).
Sterna spp.*	1	WA.	OCT.
paradisaea	1	BP.	NOV.
fuscata	1	AW.	SEP.
TOTAL	200		

* Species or subspecies was not identified by the patroller.

on mainland beaches but not reported on beach patrol cards: one on Waikawa Beach (WW) in July 1975 (Edgar 1975) and the other on Ninety Mile Beach (AW) in April 1978 (Sibson 1978). As well, three White-bellied Storm Petrels were seen near the coast in 1969: two birds seen west of Cape Farewell

TABLE 3 — Coastal distribution of the seabirds more commonly found dead in 1985

SPECIES OR SUBSPECIES	COASTS AW	TA	WW	AE	BP	EC	WA	WS	NC	CN	CS	OT	SD	OI	TOTAL BIRDS
Eudyptula minor subspp.*	3445	38	48	1574	193	5	1	9	24	6	3	6	13	3	5368
Diomedea spp.*	17	2	6	2	-	-	1	6	1	-	-	-	5	-	40
chrysostoma	28	-	2	1	1	-	-	1	-	-	-	-	-	-	33
bulleri	7	-	-	-	-	-	-	1	1	-	-	-	45	-	54
cauta cauta	12	2	1	-	1	-	-	9	2	-	-	-	-	-	27
Macronectes spp.*	68	4	6	2	2	-	-	-	-	-	-	-	-	2	84
Fulmarus glacialoides	330	7	20	2	1	-	-	-	-	-	-	-	6	-	366
Daption capense	95	6	10	10	12	2	-	11	1	2	4	-	1	-	154
Lugensa brevirostris	111	1	7	-	2	-	-	-	-	-	1	-	-	-	122
Pterodroma spp.*	6	-	-	4	17	-	-	-	-	1	-	-	-	-	28
macroptera	60	2	1	24	14	-	1	4	-	-	-	-	-	-	106
lessonii	250	11	16	2	2	-	-	3	-	-	2	-	2	-	288
inexpectata	18	4	2	-	1	-	1	1	-	-	9	-	-	-	36
cookii	9	-	1	19	-	-	-	-	-	-	-	-	-	-	29
Halobaena caerulea	394	17	43	24	25	2	2	6	-	-	1	-	13	-	527
Pachyptilia spp.*	662	42	385	26	-	2	30	22	3	1	-	1	4	1	1179
vittata	20	2	7	1	-	-	-	3	-	-	7	-	-	-	40
salvini	35	2	4	-	-	1	-	1	-	-	1	-	-	-	44
desolata	94	-	5	3	3	3	-	1	-	-	-	-	-	-	109
belcheri	245	40	34	6	15	1	1	23	-	-	9	-	-	-	374
turtur	9839	126	335	187	53	43	40	243	4	7	50	-	2	-	10929
crassirostris	22	1	6	8	1	1	1	21	-	-	2	-	-	-	63
Puffinus spp.*	25	2	11	-	-	-	-	2	1	-	-	21	-	-	62
carneipes	31	2	4	99	29	-	-	1	-	-	-	-	-	-	166
bulleri	277	11	26	95	23	2	2	15	1	1	-	-	-	-	453
griseus	963	57	91	366	213	23	6	90	8	15	6	4	45	-	1887
tenuirostris	231	12	7	77	27	1	-	-	8	9	2	1	4	-	379
gavia	1497	114	88	436	214	6	3	20	4	2	7	-	-	-	2391
huttoni	37	-	7	7	5	-	-	5	-	9	2	-	-	-	72
assimilis	36	2	3	23	13	1	-	-	-	-	-	-	-	-	78
Pelagodroma marina	16	1	-	6	13	-	-	-	-	-	12	-	-	-	48
Pelecanoides urinatrix	568	57	88	133	59	-	5	63	2	3	1	-	9	-	988
Sula bassana	296	17	9	117	39	10	-	-	6	1	-	1	-	-	496
Phalacrocorax varius	14	-	-	11	18	-	-	-	-	1	-	-	-	-	44
Stictocarbo punctatus punctatus	1	1	-	-	-	-	-	1	-	14	51	24	3	-	95
Larus dominicanus	229	65	63	48	13	25	2	26	5	6	18	31	3	-	534
novaehollandiae	97	4	9	109	18	1	-	7	1	20	4	6	1	-	277
Sterna striata	78	12	11	12	6	-	-	-	-	-	3	9	-	-	131
TOTALS	20163	664	1356	3434	1033	129	96	595	72	98	195	104	156	6	28101

* Species or subspecies was not identified by the patroller.

in November (Jenkins 1970) and one near the Poor Knights Islands in December (Croxall 1970).

In the New Zealand region, the White-bellied Storm Petrel nests on Macauley and Curtis Islands of the Kermadec group. Elsewhere in the South Pacific Ocean, it breeds on Lord Howe, Rapa and Juan Fernandez Islands. In the South Atlantic Ocean it breeds on Gough and Tristan da Cunha Islands (Imber 1985b). The species is a late summer breeder, laying in January-February and the chicks leaving the burrows from late April to July (Serventy

TABLE 4 — Monthly distribution of the seabirds more commonly found dead in 1985

SPECIES OR SUBSPECIES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL BIRDS
Eudyptula minor subspp.*	231	293	757	591	417	162	107	74	204	232	1919	381	5368
Diomedea spp.*	3	1	3	-	3	1	7	3	7	3	7	2	40
chrysostoma	-	2	-	-	1	1	5	5	7	6	2	4	33
bulleri	-	-	1	-	2	3	-	2	44	2	-	-	54
cauta cauta	1	1	-	1	8	3	3	4	-	4	2	-	27
Macronectes spp.*	1	2	-	-	-	5	36	20	10	3	5	2	84
Fulmarus glacialoides	-	-	-	-	-	-	-	4	210	124	22	6	366
Daption capense	3	1	-	-	2	2	49	40	20	19	16	2	154
Lugensa brevirostris	-	-	1	1	-	-	1	4	102	9	1	3	122
Pterodroma spp.●	1	5	-	3	2	-	1	1	4	1	8	2	28
macroptera	25	15	1	7	3	1	8	13	8	2	3	20	106
lessonii	13	2	2	-	1	2	8	14	35	171	31	9	288
inexpectata	14	7	1	5	2	-	1	3	-	-	1	2	36
cookii	4	1	-	4	-	-	-	-	-	-	5	15	29
Halobaena caerulea	1	-	-	-	-	4	17	61	241	173	22	8	527
Pachyptila spp.*	48	87	80	13	49	13	95	180	321	140	104	49	1179
vittata	2	-	1	-	3	6	6	7	2	5	7	1	40
salvini	-	-	-	1	3	-	16	13	8	-	2	1	44
desolata	-	-	-	1	20	6	23	18	36	2	2	1	109
belcheri	2	-	-	-	1	2	81	223	57	5	3	-	374
turtur	125	45	30	4	38	24	326	737	8955	274	272	99	10929
crassirostris	-	-	-	-	1	-	-	55	7	-	-	-	63
Puffinus spp.*	5	1	5	-	26	4	4	2	2	3	3	7	62
carneipes	13	37	9	8	6	3	2	-	-	3	44	41	166
bulleri	42	28	11	9	25	5	4	5	25	180	66	53	453
griseus	50	28	57	8	47	16	11	8	16	113	1145	388	1887
tenuirostris	15	4	6	-	41	25	5	1	1	3	10	268	379
gavia	97	78	44	27	22	35	162	735	398	193	365	235	2391
huttoni	8	1	3	-	-	-	2	1	10	8	25	14	72
assimilis	4	2	2	1	2	2	5	14	21	4	14	7	78
Pelagodroma marina	2	3	4	2	5	-	-	1	13	6	6	6	48
Pelecanoides urinatrix	48	9	1	3	26	48	291	213	131	45	85	88	988
Sula bassana	27	54	10	10	10	15	15	29	145	48	77	56	496
Phalacrocorax varius	-	7	2	2	7	1	6	3	2	5	2	7	44
Stictocarbo punctatus punctatus	2	15	22	7	15	4	7	6	6	6	4	1	95
Larus dominicanus	26	54	56	55	60	67	51	45	20	25	33	42	534
novaehollandiae	119	22	19	5	8	8	11	13	21	10	21	20	277
Sterna striata	4	4	5	6	13	4	7	7	8	11	44	18	131
TOTALS	936	809	1133	774	869	472	1373	2564	11097	1838	4378	1858	28101

* *Species or subspecies was not identified by the patroller.*

et al. 1971, Imber 1985b). Outside the breeding season the birds are thought to disperse into the tropics.

A Manx Shearwater picked up from Waikanae Beach (WW) in January is only the second record for the Scheme (Table 2). The first specimen was found near Pukerua Bay (WW) in June 1973. Tennyson (1986) provided a detailed description of the 1985 bird and a useful list of features that distinguish the species from the Fluttering Shearwater and Hutton's Shearwater *(Puffinus huttoni)*.

Several species were found in greater numbers in 1985 than in any previous year. Since 1969 the number of Little Blue Penguins found per year has ranged from 219 in 1970 to 4741 in 1974. By comparison, 5368 were found in 1985. Most of the birds were found on Auckland West (3445) and Auckland East (1574) beaches (Table 3). The main months of mortality were March-April (1348) and November (1919). The increased mortality in autumn is quite common for the Little Blue Penguin. It coincides with fledglings first entering the sea, when adults attempt to accumulate fat reserves to sustain their moult fast and when they try to regain condition after the moult (Powlesland 1984). Thus, the increased penguin mortality in autumn occurs, presumably, because some fledglings have difficulty catching enough food and because poor foraging conditions for adults coincide with their increased food requirements associated with the moult. The reason for the unusually high mortality in November 1985 is not known. At that time, breeding birds along the Auckland coasts would have been incubating or raising young chicks.

In 1985, 54 Buller's Mollymawks were found dead, many more than the previous highest annual total of 16 in 1982. Of the 54 birds found, 44 were found in September on Mason Bay, Stewart Island (SD). Many were assessed to have been on the beach for more than a month and so the 44 may have come ashore over several months. An estimated 10,000-11,000 pairs of Southern Buller's Mollymawk *(Diomedea b. bulleri)* breed near Stewart Island on the Solander Islands and The Snares (Cooper *et al.* 1986), but it is unusual to find so many washed ashore on the south-west coast of Stewart Island.

Usually 50-100 White-headed Petrels are found each year, but 288 were picked up in 1985. The previous highest annual total was 213 in 1984. Most of the 1985 White-headed Petrels (250) were picked up from Auckland West beaches (Table 3) in spring (Table 4). This spring peak in mortality of White-headed Petrels is typical for New Zealand; see the review section later.

As for the previous species, more Australasian Gannets and Pied Shags were found in 1985 than in previous years. Of the 496 gannets picked up in 1985, most were found on Auckland West (296) and Auckland East (117) beaches. Generally, 10-60 gannets were found each month in 1985, except in September when 145 were picked up (Table 4). It seems unlikely that incubation, the stage of the breeding cycle for most gannets in September (Robertson 1985), would have increased their mortality so much. Possibly, the mortality was a consequence of the south-east gales that passed over the North Island in August.

All but one of the Pied Shags found in 1985 were picked up from Auckland West (14), Auckland East (11) and Bay of Plenty (18) beaches

There was no seasonal pattern to the mortality, a few shags being found in each month, except January (Table 4).

Usually, 100-200 Red-billed Gulls are found each year, but the total was 277 in 1985. The previous highest annual total was 245 in 1977. Most of the 1985 gulls were found on Auckland West (97) and Auckland East (109) beaches. Each month, 10-20 birds were found, but in January 119 were found (Table 4). In January, fledglings are leaving the colonies (Mills 1985) and having to learn to forage. Thus, the increased mortality in January 1985 was probably mainly the result of these inexperienced foragers dying of starvation.

The 1985 tally of White-fronted Terns was 131, surpassing the previous highest annual total of 112 in 1982. Most of the 1985 terns were found on Auckland West beaches (78), and the largest number per month was picked up in November (44). During November nesting terns lay and incubate (MacCulloch 1985), activities unlikely to increase mortality. The reason for the higher numbers than usual found dead in 1985 is not obvious.

Wreck

A feature of the 1985 results was a wreck of Fairy Prions, Fulmar Prions and Fluttering Shearwaters in August-September (Table 4), resulting in the highest annual totals for these species. In addition, large numbers of Diving Petrels *(Pelecanoides urinatrix)* were picked up, but they began arriving on the beaches in July.

On 26 July easterly winds of up to 55 km/h developed at the Chathams Islands. By the next day a low of 985 mb, centred just north of the Chathams, resulted in hurricane-force easterly winds averaging 100 km/h lashing the islands. Elderly residents at the Chathams could not recall a worse storm; it caused much damage to buildings and fishing boats. Gale-force easterly winds extended across to New Zealand, battering the coastline from East Cape to the Otago Peninsula with high seas and heavy rain. On 28 July the winds continued to blow at 30-60 km/h, but by 29 July the storm had passed and light winds then blew from the westerly quarter on to the North Island west coast.

During the first 10 days of August, predominantly light easterly winds blew on to the northern North Island. This was followed by nearly a fortnight of westerly winds on to the Auckland West coast, which reached 70 km/h on 19 August. Similarly, from 3 to 9 September, westerly winds of up to 60 km/h blew persistently on to that coast.

The total of 10,931 Fairy Prions found in 1985 is about double the previous highest annual total of 5118 in 1975. Over 90% of the Fairy Prions in 1985 were picked up from Auckland West beaches (Table 3). Although slightly more Fairy Prions than usual were picked up in August from these beaches, it was not until the second week of September that patrollers found very large numbers. For example, 24 Fairy Prions per kilometre were picked up from 35 km of Muriwai Beach on 8 September and 34 per kilometre from 88 km of Ninety Mile Beach and north of Herekino Harbour on 14 September.

The Fairy Prion breeds on many islands in the New Zealand region, including some of the subantarctic islands, and is circumpolar in its distribution (Harper 1980). It is a numerous species, with a huge population breeding on Stephens Island alone (D. G. Newman, pers. comm.). During the non-breeding season (March-August), the birds remain about New Zealand, the largest concentrations being east of Northland and in the Cook Strait-South Taranaki Bight and Foveaux Strait areas (Harper 1985, J. A. F. Jenkins, pers. comm.).

Wrecks of Fairy Prions are relatively common along the North Island west coast. It seems that poor food supplies or rough seas, which reduce access to prey, result in a loss of fat reserves, particularly when the birds have to battle against persistent westerly winds that would otherwise force them inland. These factors contribute to the wrecks, and it is likely that the latter factor brought about the 1985 wreck. Although a record number of Fairy Prions was found, it represents a very small proportion of the total New Zealand population.

In total, 63 Fulmar Prions were found in 1985. That this is a remarkable occurrence is evident when one recalls that the first Fulmar Prions were reported by patrollers only in 1970 and that only 22 specimens were found from 1970 to 1984. Although many of the 1985 Fulmar Prions were found on the Auckland West and Wellington South coasts, some came from the other North Island coasts (Table 3). Unlike the Fairy Prions, 87% of the Fulmar Prions were found in August, not September (Table 4). Many of the Wellington South birds came ashore in the first week of August, suggesting that they were Chatham Island birds blown on to mainland beaches by the easterly gales.

As well as nesting at the Chatham Islands, Fulmar Prions breed on the Western Chain of The Snares and on the Bounty, Auckland and Heard Islands (Harper 1980). The population associated with each island is not large, and the birds do not seem to disperse far from their breeding sites at any time of year (Harper 1980). This sedentary habit and relative scarceness of the Fulmar Prion are probably the main reasons why so few are found by beach patrollers.

In 1985, 2391 Fluttering Shearwaters were found, compared with the previous highest annual total of 1538 in 1978. Generally, 200-500 were found each year from 1970 to 1984. Nearly all the Fluttering Shearwaters in 1985 were found on beaches of the North Island, particularly Auckland West (1497) and Auckland East beaches (436). Unlike the monthly results for the Fairy Prion and Fulmar Prion, although there was a peak in recoveries of Fluttering Shearwaters in August, large numbers were also found from September to December (Table 4). Presumably, the large number of birds found in August resulted from the stormy conditions, but why so many were found subsequently is not known.

The Fluttering Shearwater breeds only about New Zealand, nesting on numerous islands and islets from the Three Kings Islands in the north to as far south as Cook Strait. It inhabits inshore and continental shelf waters rather than the deep sea (Imber 1985b).

Nearly a thousand Diving Petrels were picked up in 1985, two-thirds of these coming from Auckland West beaches. The 1985 total (988) is the second highest annual total for the species, but the 1975 wreck (3580) was far larger. Most of the Diving Petrels in 1985 were found in July-August. Many of them came ashore in the first fortnight of July, when westerly winds blew on to the west coast of the North Island on most days. However, the winds were always less than 20 knots, and so weather was probably not a major factor in the death of the birds.

Miscellaneous birds

Birds other than seabirds recovered in 1985 totalled 292. There were 62 magpies, 26 Black Swan, 18 each of Mallard and Starling, 17 Blackbird, 14 Rock Pigeon, 11 duck species, nine each of Grey Duck, Australasian Harrier and Indian Myna, eight each of Pheasant and Pied Stilt, seven each of Paradise Shelduck and South Island Pied Oystercatcher, five each of domestic geese, domestic turkeys, Pukeko, Bar-tailed Godwit, passerine species and Song Thrush, four each of White-faced Heron and domestic fowl, three each of California Quail, New Zealand Pigeon and New Zealand Kingfisher, two each of Variable Oystercatcher, Golden Plover, Chaffinch and House Sparrow, and one each of Grey Teal, New Zealand Shoveler, Spur-winged Plover, Knot, North Island Kaka, Red-crowned Parakeet, Shining Cuckoo, Morepork, Little Owl, Welcome Swallow, New Zealand Pipit, Yellowhammer, Greenfinch and Goldfinch.

Pterodroma RECOVERIES 1960-1984

The following is a summary of the coastal and monthly distributions of some of the *Pterodroma* species found by patrollers during the past 25 years. Only one Kermadec Petrel *(P. neglecta)* (Powlesland 1983) and one Bird of Providence *(P. solandri)* (Powlesland 1986) have been found to date. The data for the six Stejneger's Petrels *(P. longirostris)* and 90 Black-winged Petrels *(P. nigripennis)* found during 1960-1983 were described and discussed by Powlesland (1985)

To test whether the annual pattern of recovery for each species depicted in Figure 1 differed from the theoretical situation whereby an equal number of birds were found each month, I used the Kolmogorov-Smirnov one-sample test (Siegel 1956, p.47).

GREY-FACED PETREL *P. macroptera*

Two subspecies of this petrel are recognised, but patrollers did not distinguish between them. *P. m. gouldi* nests on and around the North Island, from the Three Kings south along the west coast as far as New Plymouth (TA), and as far south as Gisborne (EC) on the east coast. The main colonies occur on islands to the east of the North Island: Mokohinau Islands, Mercury and Alderman Islands, White Island, Whale Island and the Hen and Chicken group (Imber 1985b). This subspecies is fairly sedentary, remaining throughout the year in the South Pacific Ocean and Tasman Sea from 30° S to at least 47° S, and from the east coast of Australia to at least 145° W (Imber 1985b). This sedentary habit relates to the long breeding cycle of the species; successful breeders feed young until December, then moult and return to the colonies in March or April to prepare their burrows for the next breeding cycle (Imber 1985b).

The nominate subspecies *(P. m. macroptera)* breeds on several islands in the South Atlantic and Southern Indian Oceans, as well as islands off the south coast of Western Australia (Harrison 1983). A few birds from Western Australia may well be washed ashore on New Zealand beaches.

During 1960-1984, patrollers found 919 Grey-faced Petrels. About 60 petrels were found in most years from 1970 to 1984, the highest annual total being 119 in 1981. Overall, the average rate of recovery was 1.68 birds per 100 km of coast covered. Of the coastal regions, Auckland East had the

TABLE 5 — Rate of recovery (number of petrels found per 100 km of beach covered) of five species of *Pterodroma* on each coast during 1960-1984

SPECIES	AW	TA	WW	AE	BP	EC	WS	NC	WD	CN	CS	OT	SD	OI	Total
P. macroptera	1.74	0.65	0.09	4.33	3.89	-	0.27	-	-	0.16	-	-	0.17	-	1.68
P. lessonii	4.91	1.36	1.69	0.20	0.31	0.61	0.27	0.85	0.56	0.11	1.03	0.07	0.34	-	2.67
P. inexpectata	1.23	0.38	0.29	0.08	0.22	-	0.10	0.17	0.19	0.05	0.82	0.13	9.57	0.66	0.89
P. pycrofti	0.04	-	0.01	0.13	0.04	0.15	-	-	-	-	-	-	-	-	0.04
P. cooki	0.47	0.17	0.08	3.48	0.44	-	-	0.17	-	-	-	-	0.26	-	0.79

greatest rate of recovery (4.33 birds/100 km of coast covered), followed by Bay of Plenty (3.89) and Auckland West (1.74) (Table 5). These results are as expected from the bird's breeding distribution about the northern half of the North Island.

Figure 1 shows that the monthly rate of recovery changed during the year ($p<0.01$), being greatest in summer and least in autumn. The Grey-faced Petrel is a winter breeder, laying in late June-July and the chicks leaving the colonies mainly in late December (Imber 1985b). Thus, the summer peak in mortality is probably the result of recently fledged young dying about the northern coasts because of their poor foraging ability. The reduced mortality in March-April occurs because only breeders are present at the colonies, and many of these desert the colonies after mating in April to feed at sea for about two months before returning to lay (Imber 1985b). The non-breeders do not return in large numbers to the colonies until late May.

WHITE-HEADED PETREL *P. lessonii*

In the New Zealand region, this petrel breeds on the Antipodes Islands, Auckland Islands and Macquarie Island (Falla *et al.* 1979). In addition, it nests on Iles Crozet and Kerguelen Island in the Southern Indian Ocean (Warham 1985). As in the Grey-faced Petrel, the breeding adults are not markedly migratory, being absent from Macquarie Island for only about 11 weeks between breeding cycles (Warham 1985). However, adults range far from the nest to feed (Warham 1985) and immatures have a more-or-less circumpolar range from about 30°S to Antarctica (Harrison 1983).

In total, 1465 White-headed Petrels have been found, making it the most numerous *Pterodroma* species picked up by patrollers. The species was found at a rate of 2.67 birds per 100 km of beach covered from 1960 to 1984. It was found most on beaches of the western North Island, Auckland West

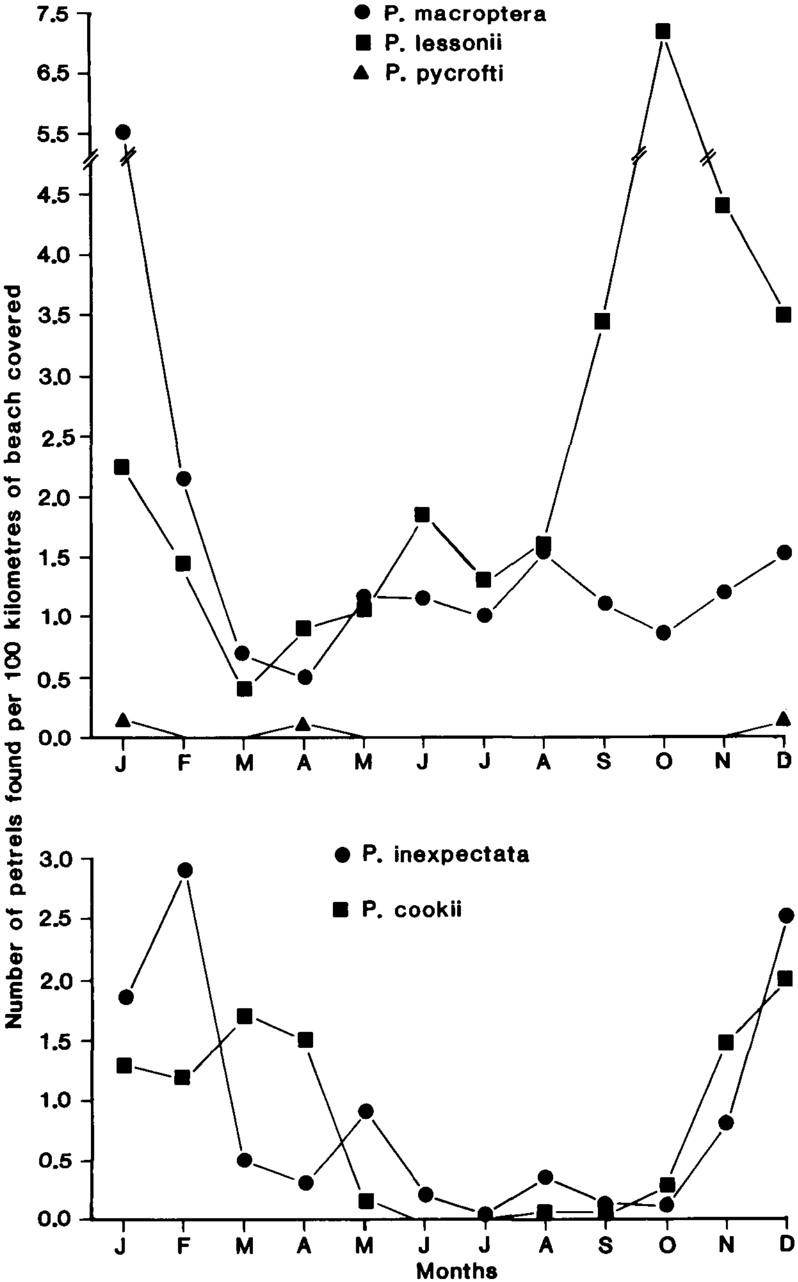

FIGURE 1 — Monthly rate of recovery (number found dead per 100 km of beach covered), of five *Petrodroma* petrels during 1960-1984

having a much higher rate of recovery (4.91 per 100 km of beach covered) than Taranaki (1.36) or Wellington West (1.69) (Table 5). This distribution probably reflects the influence and prevalence of on-shore winds and suitable currents for casting the dead birds ashore, rather than the relative abundance of White-headed Petrels in waters adjacent to Auckland West, Taranaki and Wellington West beaches (Warham 1985).

The monthly rate of recovery of White-headed Petrels changed markedly during the year ($p<0.01$). From a low in March of 0.4 birds per 100 km of beach covered, the mortality rose gradually in winter to a peak of 7.3 birds in September and remained relatively high in summer (Figure 1). As the birds lay from late November to mid-December and the eggs hatch in February (Warham 1967), the spring-summer mortality is probably the result of non-breeders dying. A high proportion of White-headed Petrels beach-wrecked in August-September are in primary moult and so have a reduced flying capability. Probably these are birds 1-5 years old as the older (breeding) birds would moult in July-August (M. J. Imber, pers. comm.). Jenkins (1982) reported regular sightings of flocks of White-headed Petrels feeding and rafting in the Tasman Sea at about 35°S, 155°E in July and August. It is not known whether these birds remain in the Tasman Sea during spring and summer and so are relatively close to our shores, or whether the peak in mortality results from spring gales forcing the birds north from about the breeding islands south of New Zealand.

MOTTLED PETREL *P. inexpectata*

Although this petrel probably used to breed on some ranges and hills of the North and South Islands, it now breeds mainly at The Snares and on the islands about Stewart Island (Warham 1985). The birds return from their Northern Hemisphere wintering grounds to The Snares in late October (Warham 1985). Laying occurs in December and the fledglings depart in May-early June. Once the raising of fledglings is completed, the Mottled Petrel undertakes a transequatorial migration in April-June to its wintering grounds in the subarctic waters of the North Pacific Ocean (Nakamura & Tanaka 1977).

Generally, patrollers find about 30 Mottled Petrels annually, the greatest number being 68 in 1982. During 1960-1984, 487 of these petrels were found at an average rate of 0.9 birds per 100 km of beach covered. As expected from the distribution of its breeding colonies, most Mottled Petrels were found on Southland beaches (9.57 birds per 100 km of coast covered). The coast with the next highest rate of recovery was Auckland West (1.23) (Table 5).

The monthly rate of recovery, as shown in Figure 1, changes significantly through the year ($p<0.01$). The return time of the Mottled Petrel to the New Zealand region is evident from the marked increase in the rate of recovery in November over that of the previous two months (Figure 1). The mortality remains high from December (laying) to February (hatching) but is much reduced from March to June. In the latter period breeders are rearing chicks; the chicks leaving in May and early June (Warham 1985).

The greater mortality of the Mottled Petrel in summer, rather than in autumn, may be related to the presence of non-breeders about the colonies.

Many of these birds may be weakened by the migration and be inexperienced at foraging in New Zealand waters, and so probably succumb when conditions prevent ready access to prey. By March these non-breeders, and perhaps unsuccessful breeders, start departing from the colonies on their rapid transequatorial migration. Thus, in autumn, mainly birds feeding chicks are present about New Zealand (which, as a class, are likely to be successful foragers), resulting in the low rate of recovery from March to May. During June, the last nestlings and adults leave, and so few Mottled Petrels are found on beaches from July to October. The slight increase in recoveries in August is mainly the result of 15 of the August birds being found in 1978 on Mason Bay, Stewart Island (SD), more than a month after being washed ashore.

SOFT-PLUMAGED PETREL *P. mollis*

This petrel has a wide distribution, breeding on the Tristan da Cunha group and Gough Island in the South Atlantic Ocean and on Crozet, Marion and Prince Edward Islands, and probably on Kerguelen Island, in the Southern Indian Ocean (Imber 1983, Warham 1985). The species was first seen in the New Zealand region in February 1969, when a few were captured flying over Antipodes Island (Warham & Bell 1979). From the observations of Imber (1983) at Antipodes Island in November-December 1978 it is likely that the species breeds there. Elsewhere in the Southern Hemisphere this petrel returns to its colonies in August-September, lays in November-December, and the young leave the islands in May.

Presumably because of its rarity in New Zealand coastal waters, only four Soft-plumaged Petrels have been found by patrollers. The results for these birds are: 1971, BP, November; 1974, AE, December; 1978, WS, June and 1984, BP, November. In addition, there are three other records of Soft-plumaged Petrels in New Zealand. Two birds were found alive; one in the Hutt Valley (WS) in May 1971 (Warham 1985) and the other on Petone Beach (WS) in June 1983. The third bird was found dead, also on Petone Beach, in June 1983 (Booth 1984). That at least one, and probably all three, were fledglings, virtually confirms breeding in the New Zealand region (M. J. Imber, pers. comm.).

PYCROFT'S PETREL *P. pycrofti*

This species has a restricted breeding distribution, nesting only on islands along the north-eastern coast of the North Island: Stephenson Island, Aorangi Island, Hen Island, Lady Alice Island and Red Mercury Island (Bartle 1968, Williams & Given 1981). Birds return to their colonies in October, the eggs are laid in November-early December, and the chicks leave in late March-April (Bartle 1968, Dunnet 1985). Pycroft's Petrel probably spends the non-breeding season (May-September) over the North Pacific Ocean.

To date, patrollers have found only 23 Pycroft's Petrels. This is not surprising considering its rarity, the world population numbering only a thousand or so (Williams & Given 1981). The most Pycroft's Petrels found beach-wrecked in any year was five in 1971. During 1960-1984, only one Pycroft's Petrel was picked up for every 2500 km of beach covered. This petrel has been found only on North Island beaches, mainly on Auckland East and East Coast North Island beaches (Table 5).

The monthly rate of recovery did not change significantly through the year (Figure 1). Almost all the birds were picked up in the breeding season (November-April). The mortality is greatest in December and January, when non-breeders are very evident at the colonies (Bartle 1968, Dunnet 1985).

NEW CALEDONIAN PETREL *P. leucoptera caledonica*

Patrollers did not distinguish between the two subspecies of *P. leucoptera*. However, all specimens submitted to museums for critical examination have proved to be New Caledonian Petrels rather than Gould's Petrels *(P. l. leucoptera)* (Imber & Jenkins 1981). Therefore, all specimens found beach-wrecked are assumed for the purposes of this paper to have been of the *caledonica* subspecies.

The New Caledonian Petrel nests along the central mountain range of New Caledonia. Although no study has described the timing of the petrel's breeding cycle, it is known to lay in late December and the chicks probably leave the burrows in May (Imber 1985b).

Before 1960, 11 New Caledonian Petrels were found beach-wrecked, all on Muriwai Beach (AW) (Bull 1943, 1946). From 1960 to 1984, 13 of these petrels were found. Most were found on North Island west coast beaches (AW 8, TA 1, WW 2), the other two being from Auckland East beaches. That most birds were found on western beaches is to be expected, because all sightings of *P. leucoptera* made by J. A. F. Jenkins have been to the west of New Zealand (Imber & Jenkins 1981). Sightings of the species in the Tasman Sea extended as far south as Foveaux Strait (SD) (Imber & Jenkins 1981), and so corpses can be expected on western South Island beaches also.

Beach-wrecked New Caledonian Petrels have been found in January (5), April (10), May (3), June (1), November (1) and December (3). The timing corresponds broadly with that of sightings of *P. leucoptera* in the Tasman Sea; December to April inclusive (Imber & Jenkins 1981). As nesting New Caledonian Petrels would be confined to the seas about New Caledonia from November to May, most of the birds found on New Zealand beaches were probably non-breeders. Corpses are lacking on New Zealand beaches from July to October because the birds are then in the eastern tropical Pacific (Imber & Jenkins 1981).

COOK'S PETREL *P. cookii*

In winter this petrel inhabits the eastern central Pacific, mainly between 13°S and 23°N (Imber 1985b). However, not all birds desert the colonies; a few can usually be heard calling on dark nights in June over Little Barrier Island *(pers. obs.)*. Those that migrate to the central Pacific Ocean begin returning to their nesting islands in late August. Cook's Petrels nest on three islands around New Zealand: up to 50,000 pairs on Little Barrier Island (AE), fewer than 20 pairs on Great Barrier Island (AE) and about 100 pairs on Codfish Island (SD) (Imber 1985b). Formerly, about 20,000 pairs bred on Codfish Island, and this population may grow to its former abundance now that the introduced weka *(Gallirallus australis)* has been eradicated from the island. Laying occurs from late October to early December on Little Barrier Island but is up to a month later on Codfish Island (Imber 1985b.)

On the northern islands the chicks hatch mainly in late December and depart from the island from mid-March to mid-April.

Generally, about 25 Cook's Petrels have been found annually during the past 10 years, 92 in 1981 being the highest annual total. From 1960 to 1984, 434 petrels were found at a rate of 0.8 birds per 100 km of beach covered. This rate of recovery seems low, considering the large number that breeds on Little Barrier Island. Presumably this result relates, in part, to the adjacent coastline (AE) not having currents and winds which regularly force dead seabirds ashore, as happens on the west coast of the North Island. Even so, Auckland East had the highest rate of Cook's Petrel recoveries at 3.48 birds per 100 km of beach covered, followed by Auckland West (0.47) and Bay of Plenty (0.44) (Table 5).

The monthly rate of recovery of the Cook's Petrel changed markedly through the year ($p<0.01$) (Figure 1). After August the mortality increased gradually, when the birds started returning to Little Barrier Island, reaching a peak in December. The rate of recovery dropped in January and February but increased again in March and April, coinciding with the departure of the nestlings. In May, immediately after the breeding season, very few Cook's Petrels were found beach-wrecked, and none has been picked up in June or July.

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