BIOLOGY OF THE BULLER'S SHEARWATER (*Puffinus bulleri*) AT THE POOR KNIGHTS ISLANDS, NEW ZEALAND

By PETER C. HARPER

ABSTRACT

From 1963 to 1981 data were collected on the breeding of the Buller's Shearwater. The world population, roughly 2.5 million birds, occupies 7 of the 12 islands, islets, and stacks of the Poor Knights Islands (35°30'S 174°44'E).

Buller's Shearwaters return from their 4.5 month trans-equatorial migration on about 10 September. Numbers build up rapidly with breeding birds digging burrows averaging 1.01 ± 0.2 m in length. Caverns, caves, and Maori stone walls also serve as nest sites.

Nest refurbishing is complete by about 26 October, when copulation occurs. The prelaying exodus follows about 32 h later, with most birds absent from the islands' vicinity for about 30 days until 25 November.

Eggs appear from 26 to 30 November. Females without nests lay eggs on the ground until 3 December; these eggs are eaten by tuataras and small lizards. Average dimensions of 74 eggs were 65.44 ± 0.29 x 42.96 ± 0.22 mm; and average weight of 27 fresh eggs 66.76 ± 0.85 g. Surface eggs are narrower than burrow eggs.

The incubation period is c. 51 days with both sexes sharing duties. Four nights is the average shift; females sit the first night and following day. Hatching occurs about 19 January; most fledglings leave the islands in early May.

Most of the few adult *bulleri* that die on the breeding grounds are ensnared in tree saplings.

Numbers on Aorangi have expanded rapidly from c. 100 pairs in 1938 to about 200 000 pairs in 1981. *P. bulleri* is an aggressive coloniser, displacing gadfly petrels and smaller shearwaters for nesting space, and may soon be colonising the Three Kings and other nearby islands.

INTRODUCTION

The Buller's Shearwater is a subtropical surface-feeder that breeds only on the Poor Knights Islands off the east coast of northern New Zealand. It is distinctive for the brown and grey pattern of its upperparts, its all-white underparts, slender body proportions, relatively broad wings, and long wedge-shaped tail (Harper & Kinsky 1978: Fig. 13 & Plate 13). Its nearest living relative is the Wedge-tailed

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Shearwater *(Puffinus pacificus)* of the subtropical and tropical Pacific and Indian Oceans. Both these birds once comprised the subgenus *Thyellodroma* of Stejneger, which Stejneger distinguished from subgenus *Puffinus* because of their long cuneate tails — nearly half the length of the wing (Murphy 1951). With a wingspan of just under a metre (995 mm) and a total body length of about 476 mm, a Buller's Shearwater in good condition weighs about 412 g — about half that of the similarly sized pursuit-plunging Sooty Shearwater *(Puffinus griseus)*.

The Buller's Shearwater was discovered in October 1884 when Walter L. Buller found a storm-tossed female on Waikanae Beach; in 1888 Salvin formally described the bird as *Puffinus bulleri* in honour of its finder.

Its breeding grounds remained unknown for 30 more years. Six further specimens were recorded in New Zealand, and 16 were shot by collectors off Point Pinos on the coast of California (Loomis 1918). The bird was better known in California than in New Zealand until its breeding place was found in December 1915 by William Fraser, a Whangarei Harbour Board engineer whose interests included visiting offshore islands. It was Fraser who rowed R. A. Falla ashore at the Poor Knights Islands in December 1923, and Falla's paper recording the discovery of its nesting place appeared in *Emu* in 1924.

Although the Buller's Shearwater is now well known in New Zealand and it is familiar overseas as the New Zealand Shearwater or the Grey-backed Shearwater, its breeding biology and ecology at the Poor Knights are very poorly known. As it is an endemic species confined to this small island group, concern has been expressed in recent years for its welfare; the purpose of this paper is to bring together what is known about the bird and to discuss its status.

METHODS

In 14 visits totalling 189 days on Aorangi between 1963 and 1981 to study Fairy Prions *(Pachyptila turtur)* (see Harper 1976) I have collected anecdotal notes on *bulleri*. I foresee the greatest problem in making a detailed study of Buller's Shearwaters is that they readily desert nests. Even when I took great care with nest-observation covers and periodic monitoring of nests, I found that incubating birds would leave nests and not return for 4-5 days. They are acutely sensitive to any disturbance whatsoever.

Birds were banded with monel or stainless steel bands from the Banding Office, Wildlife Service, Department of Internal Affairs. Field measurements were made with 150 mm stainless vernier calipers, a 1-metre stainless folding rule, and 500 g (± 2 g) or 1000 g (± 2 g) Pesola spring balances. Eggs were weighed with a smaller 100 g (± 1 g) Pesola balance. Regurgitations were preserved in 70% ethyl alcohol for further analysis.

Burrows were measured and checked for occupancy with a Rabone Chesterman Lockflex flexible spring tape or a 6 m Evans Tru-Lok tape. If you insert your left arm into a burrow until you encounter a bend in the burrow, you can feed in the stiff yet flexible tape with the right hand and guide it around the corner with the left-hand fingers to the end of the burrow. This is a simple way of measuring long burrows. You can detect the softness of a sitting bird with the tape and also hear it rustling its feathers. If you rattle the tape, an adult bird leaves its nest and scuffles to the burrow entrance, where you can capture it. This technique works well with some shearwaters, with prions, and with diving petrels such as *Pelecanoides georgicus,* which tunnel 1.5 m deep into compacted sand dunes on Codfish Island.

I assessed rates of population increase by counting *bulleri* burrows in prion study areas, recording the takeover of other petrels' burrows by *bulleri;* by noting new burrows appearing in places previously having no burrows, and by general observations. From all this information I made estimates in 1981 of the population for Aorangi and the total *bulleri* population for the Poor Knights.

HISTORY

The Poor Knights Islands are a Nature Reserve administered by the Hauraki Gulf Maritime Park Board, Auckland. They comprise two islands of volcanic origin and a small flotilla of stacks and rocks in subtropical waters 24 km off the east coast of Northland. The highest point is Oneho Hill (218 m) on the island of Aorangi. Regenerating coastal forest covers all but the steepest precipices. For botanical notes see Cockayne (1906) and Oliver (1925).

Before 1823 both the larger island, Tawhiti Rahi (132 ha) and Aorangi (68 ha) were occupied by some 300 Maoris, whose fortifications were visible to Captain James Cook when he discovered the islands on 26 November 1769 (Beaglehole 1955). Much of the vegetation had probably been removed at this time for cultivation of vegetables and fortifications (Oliver 1925, Falla, pers. comm. 1973). Pigs were later brought to Aorangi by its Maori residents and kept secure as food and barter. Also used for barter, and considered more appetising than the " northern muttonbirds " *(Pterodroma macroptera),* was the Buller's Shearwater. In a letter to W. R. B. Oliver dated 11 July 1955, William Fraser wrote, " Rako is the Maori name of Puffinus Bulleri, and my old Ngatiwai informants of 40 to 50 years ago on this coast would tell me that their relations of the old time on the Poor Knights made a trade with the mainlanders in preserved young rako, as this species of mutton bird was in greater demand than the more common kind, and that the Maori protected the nesting places and the parent birds."

In December 1823, while the men and their chief, Tatua, were absent, the islands' inhabitants were massacred (see Fraser 1925).

The rest of the Maoris left permanently, declaring the islands tapu, or forbidden. Thereafter the pigs flourished: they stripped Aorangi bare of seedlings and ate everything palatable within reach. Petrels were rooted out of their burrows and eaten (Falla 1924, Oliver 1935). Falla found remains of *bulleri* and Fairy Prions, all " victims of the pigs' depredations " and commented that " During several hours' stay on this island no living Petrels of any kind were found, and all the burrows examined were empty." However, on Tawhiti Rahi, only 440 m away, " rako " flourished free from pig predation.

The last of the feral pigs was shot on Aorangi in 1936 and soon afterwards a low mixed forest regenerated and the seabirds re-colonised. In 1938 G. A. Buddle and C. A. Fleming found a colony of c. 100 burrows of *bulleri* " on a gently-sloping earthy shelf situated at the foot of a steep rocky face and terminating in a high cliff dropping sheer to the sea 200 feet below . . . the area at that time was shared with Prions in about equal numbers. We did not locate any other breeding areas and ascribed the presence of this colony to the fact that the ledge had probably been inaccessible to the pigs." In 1940, " the size of the colony had increased considerably and the prions had been completely ousted " (Buddle 1941). Incoming bulleri were probably from neighbouring Tawhiti Rahi, where as many as half a million birds were believed to be resident (Wilson 1959).

Other petrels were also digging in. In 1940 a further four species were reported from Aorangi: the Fluttering Shearwater *(Puffinus gavia)*, Grey-faced Petrel *(Pterodroma macroptera gouldi)*, Pycroft's Petrel *(Pterodroma pycrofti)*, Diving Petrel *(Pelecanoides urinatrix)*, and White-faced Storm Petrel *(Pelagodroma marina)*. Of these, *gavia* and *macroptera* were judged in 1940 to be the most common (Wilson 1959).

Summary of previous observations

Loomis (1918) gave measurements of 15 California specimens of *bulleri* and a detailed description of the species. He noted that " The breeding places of this Southern Hemisphere species and the route by which it reaches the vicinity of Point Pinos, California, are unknown." Six years later, Falla (1924) reported its presence at the Poor Knights Islands, reviewed its status in New Zealand, and gave a few notes on its burrow habitat, nest, eggs, and behaviour about its breeding grounds. Little further information has been added since. Brief observations were made by Buddle (1942) and Kinsky & Sibson (1959), but no breeding study of the Buller's Shearwater has been attempted.

The migration route is still not known. There is no evidence to show that they accompany Sooty Shearwaters and Short-tailed Shearwaters *(Puffinus tenuirostris)* north of the equator or that they engage in any clockwise migration around the North Pacific Ocean, but observations are lacking. Jenkins (1980) discussed the presence of

bulleri in Tongan waters but believed that the birds' migration path both to and from New Zealand waters lies well east of Tonga. Kuroda (1955, 1960) reported *bulleri* from 14.5-16 °C waters near Japan, and Wohl (1975) saw nine birds in September 1974 in the northern Gulf of Alaska. Kessel & Gibson (1976) described *bulleri* as a rare visitor to south coastal Alaska from late April to September, where it appears " singly or in twos or threes; maximum count has been 17." Campbell (1971) considered *bulleri* to be a regular autumn migrant off the British Columbia coast, and Ainley (1976) stated that " They are most numerous off California from early September to early October." Because of their scarcity south of Monterey and in the eastern Pacific south of Baja California, Ainley suggested that " Birds occurring off California probably turn towards New Zealand at about the latitude of central California."

Moulting birds have been reported not only from California waters (Loomis 1918) but also from the coast of Chile. Beck's specimens collected off Valparaiso, Chile, between 24 February and 12 March 1914 were all " moulting the quills and had nesting gonads " (Murphy 1936). These non-breeding individuals summer in the usually productive waters of the Humboldt Current while the breeding population is resident in New Zealand. At the limits of their very wide Pacific distribution, Buller's Shearwaters are frequently found at boundaries between warm and cold currents in ocean temperatures 14.5-16 °C (e.g. Japan, Kuroda 1955, 1960; California, Ainley 1976; New Zealand, Jenkins 1974).

The local movement of *bulleri* about New Zealand was the subject of a most valuable contribution by John Jenkins (1974). From summer through to late April they flock in hundreds along the east coast of the South Island of New Zealand in warm tongues of surface waters close to the Subtropical Convergence (Bartle 1974; Jenkins 1974; Harper, pers. obs). Cunningham (1948) gave measurements of 21 birds cast ashore in Palliser Bay after a southerly storm in February 1947 (see Table 1). Sea surface temperatures at the Poor Knights during the breeding season of *bulleri* range from a minimum of 16.2 °C in August to a maximum of 21.5 °C recorded in February.

THE BREEDING CYCLE

Most Buller's Shearwaters are absent from New Zealand waters from late May to early September. Jenkins (1974) observed their return. He reported that on " 11 September 1967 in a position 32°40'S 176°35'E about 160 miles north of the Poor Knights . . . for over two hours from 1630 hours until after sunset we passed through a continuous stream of Buller's Shearwaters spread out in the typical migration pattern in ones and twos and groups up to about five. Birds were seen out to the limit of visibility on both sides of the vessel's track and all were seen to be heading due south. At least several thousand birds must have passed the vessel during the late afternoon."

TABLE 1 — Measurements of Buller's Shearwaters

	Mean ± S E (mm)	Range	Number
	Loomis (1918)		
Bill length	42.3 ± 0.32	40.7 - 45	15
Wing	297.2 ± 1.68	285 - 309	14
Tail	127 ± 1.34	119 - 137	15
Tarsus	49.3 ± 0.28	47.6 - 51	15
Toe	62.0 ± 0.33	58.9 - 63.7	15
Total length	475.9 ± 3.44	460 - 493	10
Wing span	995.2 ± 4.4	980 - 1016	10
	Cunningham (1948)		
Bill length	41.33 ± 0.37	38.5 - 44.5	21
Wing	284.1 ± 2.41	268 - 300	16
Tail	no data		
Tarsus	52.45 ± 0.40	49 - 56	21
Toe	66.26 ± 0.94	61 - 68.5	21
	Buddle (1941); this study		
Bill length	41.20 ± 0.29	38.3 - 44	28
Wing	287.2 ± 2.31	275 - 300	15
Tail	125.4 ± 1.30	114 - 130	15
Tarsus	50.22 ± 0.81	47 - 57.1	17
Toe	63.64 ± 0.62	60 - 70	17

In 1981 when continuous observations were made on Aorangi from mid-August to mid-December, the first four *bulleri* appeared in flight over the island on the night of 10 September and one bird was found in a burrow. Incoming birds gradually increased until 18 September, when *bulleri* were " everywhere, either investigating or refurbishing burrows " (P. Kearton, *in litt.*). Thereafter their numbers rapidly increased as burrows were reoccupied. Corroborative information from local fishermen points to a consistent *bulleri* arrival date of the second week in September. During October and November the birds spread south along the coasts of New Zealand and remain in open continental shelf waters until late April or early May (Vooren

1972, Bartle 1974, Jenkins 1974). I observed 23 flocks, each containing between 179 and 351 birds, while at sea near Akaroa Peninsula on 19 February 1982. The birds, many in wing and body moult, were feeding on small shoaling fish.

Evening arrival on Aorangi

For much of the breeding season, Buller's Shearwaters begin arriving offshore around the islands in the late afternoon. Feeding often continues close inshore, whenever the birds pick up a shoal of trevally *(Caranx georgianus)* or similar predatory fish pursuing small prey to the surface. Storms notwithstanding, the time of the first *bulleri* over the islands at nightfall is strongly correlated with the time of sunset (Harper, in prep.). Westerly gales often delay and easterlies assist the return from the feeding grounds, which by inference, apparently lie east of the Poor Knights along the continental edge.

In places where nesting colonies are concealed by tall trees, Buller's Shearwaters usually alight briefly in the canopy branches before fluttering to the ground to land with a gentle thump; and breeding birds alight with precision near their nests. With their light weight and broad wings and tail, Buller's Shearwaters are surprisingly agile at flying along the ground under the trees and can easily flutter up and over such surface obstacles as large rocks. The strongly hooked bill, long claws, and tent-like tail make *bulleri* a deft climber of trees and sheer rock walls. Travel along the ground is accomplished in the usual shearwater waddling, but when alarmed, *bulleri* make long hops and bounds.

Eggs

Most birds favour either excavating an earth burrow 0.6 to 3.2 m long (average 1.01 ± 0.2 m, n = 179) among tree roots or occupying earth-floored caverns under large slabs of rhyolitic rock. All of 59 burrows examined had a terminal chamber sufficient to accommodate two adult birds easily. Some areas on the flat top of Tawhiti Rahi that are densely honeycombed with burrows are sufficiently clear of low ground plants to allow harriers *(Circus approximans)* to hunt prey beneath the canopy of tall gnarled pohutukawa trees (Wilson 1959). Nests are also built in caves, rock crevices, and in the convenient dark gaps within Maori stone walls. Both members of a pair dig the burrows and gather material for the nest.

Nest lining varies from the few stone fragments I found in 129 sheltered rock crevices to a substantial assemblage of leafy and twig material I found in 26 of 59 earth burrows. Sources of vegetation and twigs are chiefly the nearby canopy trees: pohutukawa *(Metrosideros excelsa)*, and karo *(Pittosporum crassifolium)*.

Birds may also strip fallen branches and seedlings of kohekohe *(Dysoxylum spectabile)* and taupata *(Coprosma repens)* to get their stiff leaves. Such trees, which are used as departure points in the morning exodus and as sources of nest material, are an important

FIGURE 1 — Adult male Buller's Shearwater incubating in a large cave. Little nest material has been used.

habitat requirement for Buller's Shearwaters nesting beneath them. Nest blocking, in which birds actively kick leaves into their burrows to disguise them (Bartle 1968) or to darken them (Warham 1960) does not occur in this species or the Wedge-tailed Shearwater. The stacks to the south of the main islands have no soil. The shearwaters improvise by nesting in the open on rock ledges and in crannies protected only by small twiggy taupata shrubs and the prostrate form of ngaio, *Myoporum laetum* var. *decumbens.* Most of the eggs in such nests were found deserted on 10 December 1964, perhaps because of the warm air temperatures (noon 24 °C with light airs).

Copulation was prevalent in the colonies on the evening of 26 October (1975 & 1981). Howling and frenetic neck-nibbling by pairs on and below ground accompanied the rush to reproduction. Even a crude imitation of the cries elicited a prompt cacophonical reply, and throughout October the island reverberated with the wailing of *bulleri* until midnight, and again two hours before dawn, when the birds departed. Many pairs (82% :211 of 256 observations) remained together in their burrows for a day and a night after copulation. Birds without nests do not remain on the island during daylight hours.

After copulation the birds leave the islands in dramatic numbers. For 30 days, while the females form their eggs (the prelaying exodus), very few *bulleri* visit the islands. The exodus by all age-groups is essentially complete from both the islands and their vicinity. None was seen at sea from the launch *Matira* during our passage to Aorangi on 15 November or our return on 21 November 1977, and during their prelaying exodus in 1964, 1973, 1977 and 1981, very few birds were seen ashore. An analysis of ring structures of *bulleri* yolks (see Grau, 1976) showed that 18 days are required for yolk formation (C. R. Grau, pers. comm.). Wedge-tailed Shearwaters at Monera I., Hawaii, have an exodus of nearly all birds for a shorter period of 6-21 days before egg-laying (Schallenberger 1973).

Some 11 weeks after their spring return to the island, *bulleri* lay their eggs. Laying for burrow-holding birds begins on 26 November and is mostly completed by 30 November: 306 of 311 (98.1%) refurbished empty nests on 27 November had eggs on 30 November (years 1964, 1973, 1979). These dates agree exactly with those obtained in 1938 and 1940 by Buddle (1941). Males return to the nests at about the same time (possibly a day or two earlier) as the females.

Females without nests continue to lay eggs on the ground until about 3 December. None of 47 such eggs was incubated by day or night and all were eventually eaten by lizards. I saw three eggs being eaten by tuataras *(Sphenodon punctatus)* and one by the large gecko *Hoplodactylus duvauceli.* The crespuscular skink *Leiolopisma oliveri* has been seen feeding from cracked *bulleri* eggs on three occasions. I know of four eggs that were still intact on the ground a year after they had been laid.

FIGURE 2 — A day-old Buller's Shearwater chick in a substantial nest in a deep cavern below ground level. The sword-like leaves are from **Xeronema callistemon**, the Poor Knights lily. All the nest material has fallen into the cavern from above.

Measurements of 104 eggs from Aorangi and Tawhiti Rahi are given in Table 2. The differences between the two populations are insignificant (L.B.2 index 120.7 for Aorangi; 120.1 for Tawhiti Rahi). There is a highly significant difference ($p<0.001$) in the width of eggs between those laid in the open, on the ground, and those laid in burrows. The lengths are barely significantly different (Table 3). The bare brood patches of 20 incubating birds measured in early January 1973 averaged 73 x 48 mm, which is 5-7 mm larger than the largest measured egg (Table 2). The egg represents about 16.4% of the net weight (with empty proventriculus) of an adult bird in good condition (taken to be about 407 g: see Table 4).

During incubation from late November to mid-January air temperatures on Aorangi are warm (noon max. shade 27 °C, noon min shade 13 °C; means 21 ° and 16 ° respectively). An embryo within a *bulleri* egg can survive 8 days without incubation in these temperatures. Absences of more than a day or two are rare, however.

If a nest and freshly laid egg are left unattended, the nest is sometimes usurped by a female without territory, and the nest then has two eggs. I recorded this on five occasions. In all five, the interloper was ejected by the owner. In three, the alien egg disappeared immediately, but in two, it was brooded under the wing for 2-7 days before disappearing.

TABLE 2 — Measurements of Buller's Shearwater eggs from Aorangi and Tawhiti Rahi

	n	Mean ± S E	Range
		Aorangi (this study)	
Length (mm)	74	65.44 ± 0.29	59.0 - 72.3
Breadth (mm)	74	42.96 ± 0.22	40.1 - 46.1
Weight (g)*	27	66.76 ± 0.85	59.0 - 74.0
		Tawhiti Rahi	
		(Falla 1924; Hamilton unpubl. data)	
Length (mm)	30	64.32 ± 0.37	60.0 - 68.0
Breadth (mm)	30	43.22 ± 0.19	41.3 - 45.1
Weight (g)	no data		

* Eggs less than 10 days from laying

Because the birds are so easily disturbed, I did not study closely the incubation shifts of partners. Eighteen observations of five banded pairs gave a median incubation stint of 4 nights (range 4-7 nights). This is much shorter than the average of 9.4 days (n = 32 incubation stints) reported for Sooty Shearwaters at The Snares by Warham *et al.* (1982), who found only two shifts of less than 8 days' duration. Females incubate for the first night and the following day (n = 37). Thereafter the male takes over for the first full incubation stint. This may not be as easy as it seems. One incident highlights the problems inexperienced birds may have in incubating eggs. An unbanded male having relieved his mate on a freshly laid egg gave me the clear impression that he had no notion of what to do with it. The bird played hockey with bill and egg for 16 minutes, during which the egg made four circuits of the nest chamber. I later found the egg in a vertical position with the sleeping bird leaning against it. The next night the egg was nestled alongside the bird under its wing. Success was eventually achieved 24 hours later.

With the precision well known for migratory shearwaters, the hatching of *bulleri* occurred in mid-January (mean 19 ± 1.7 January, range 17-26; n = 86). This gives an approximate average incubation period of 51 days. This figure is probably close to the true one, but I could not follow known-aged eggs throughout the period. Wilson (1959) reported *bulleri* hatchings on 19 January 1943. He stated " As we had found on our previous trip, that the earliest egg had been late in November, this would mean about fifty days incubation, the same period as Lockley found with his Manx Shearwaters." The dates remain the same 40 years later.

Chicks

I have almost no information on the chick stage of *P. bulleri.* Falla (1934) reported that four well-grown nestlings in down taken on 24 February were " fairly uniform in size and colour of down,

TABLE 3 — Measurement differences between surface and burrow-laid eggs of Buller's Shearwaters

Where laid	n	Length ± S E	Breadth ± S E	$L B^2$ ± S E
Surface*	33	65.93 ± 0.44	42.38 ± 0.21	118.63 ± 1.61
Burrow**	18	64.23 ± 0.71	43.78 ± 0.29	123.49 ± 1.89
P		< 0.005	<0.001	n.s.

* all presumably laid by young birds. None hatched.

** all hatched successfully

TABLE 4 — Evening and morning weights of 120 adult Buller's Shearwaters weighed in January 1973

(January)	No. of Weighings	Mean ± S E (g)	Range (g)
Evening Arrival			
16	30	452.0 ± 3.75	408 - 488
21	30	452.5 ± 5.24	385 - 490
Morning Weights			
19	30	406.8 ± 7.41	339 - 499
22	30	416.7 ± 5.88	380 - 480

which is a neutral grey, only slightly darker above than below." He continued, " Bill and feet are coloured as in the adult, but more fleshy and with dark parts less pigmented."

According to Falla, fledglings " leave the nests about the end of March, and by the end of April very few birds of this species are to be seen at sea." In a visit on 11-17 May 1976, I found 23 fledglings, together with three chicks still in mesoptyle down but with well-grown quills. It seems likely that most fledglings leave the islands about mid to late May (P. Sagar, pers. comm.; pers. obs.). Information is required. Fledglings have considerable dark flecking on the undertail-covert extremities, not a feature of adult birds. Chick mortality may be higher for late birds because, despite a careful search in high-density burrow areas, I found seven freshly dead fledglings but no young birds that had been dead for more than a week.

Unemployed birds

On Aorangi, a large percentage of the population is without a nest, or fails early to produce a chick; my guess is 40-50%. During the hours of darkness, unemployed birds arrive in great numbers and are both conspicuous and noisy. Their many activities include arriving at the colonies at any hour until 0200 h, exploring burrows (see Harper 1976), sitting about on the ground sleeping, gathering twigs and fallen leaves into small heaps on the ground, and forming twos and threes for howling sessions (Fig. 4). Their noise often stimulates chorusing and pair-bond behaviour between mated pairs of both *bulleri* and Fairy Prions on their nests. This interspecific stimulation is conspicuous and widespread throughout mixed colonies of prions and shearwaters. It can easily be initiated by a tape recording.

FIGURE 3 — Two unemployed birds spar at each other while seeking nesting territory. Fights by birds on the surface of the ground are rare.

When the evening's activities have subsided shortly after midnight, unemployed birds ignore or take little interest in one another. They sometimes ritualistically gape and spar at passing birds. This refractory period, which may last 2.5 h, seems so stupefying for the birds that I once saw a motionless bird (eyes open) succumb to gravity and fall sideways off a large rock to the ground. A prion can climb unharmed over a *bulleri* that is in this catatonic state.

Breeding birds on territory are very different, however. Burrows rarely have more than one entrance, and anything entering an occupied one must face the occupant's combined urges to flee and to fight. The result is immediate, noisy, and savage. I have, for example, seen a very large male tuatara (70 cm in length) rapidly reversing out of a *bulleri* burrow with the screaming occupant's beak embedded in its snout. On two occasions shearwaters have emerged from their burrows to attack us as we passed by some 2.5 m away. This heightened belligerence probably results from many invasions of privacy by unemployed birds. Away from areas of high density, birds were noticeably less aggressive.

The departure of nearly all birds for the prelaying exodus in late October is dramatic. Why do birds without burrows not take their pick of the huge number of cleaned-out and refurbished burrows thus abandoned? This does not happen, and returning females heavy with their eggs are not to my knowledge opposed in the reoccupation of their nests. The unemployed birds apparently do not return in important numbers for a night or two after the main influx of females, a seemingly neat arrangement that deserves study.

In late December, some three weeks before the chicks hatch, unemployed shearwaters begin leaving the islands. As a result, the colonies become much quieter and above-ground activity drops away. This departure of unemployed birds, which must relieve the adjacent food supplies and so improve the chick success rate, also deserves study. Where these birds go is not known.

Mortality

Mortality of adult *bulleri* on Aorangi is low. In 14 visits from 1963 to 1981 I have recorded 24 dead birds. Of these, 20 were caught by the legs or wings in saplings of mahoe *(Melicytes ramiflorus)*, one flying female with a shelled egg in her oviduct struck a boulder and died instantly, one died after failing to dislodge itself from under a boulder, and two were found dead from unknown causes. Harriers may take fledgling *bulleri* on their first journey to sea, but I have not seen a harrier press home an attack on flying *bulleri*. The limited banding records so far suggest that Buller's Shearwaters are long-lived birds.

Feeding behaviour and food

Buller's Shearwaters feed on a variety of prey by contact dipping and surface feeding. On only two of 211 observations of feeding

birds near the Poor Knights and Akaroa Peninsula have I seen birds plunge briefly below the surface.

The feeding technique of *bulleri* is precisely that described for its close relative the Wedge-tailed Shearwater by King (1974). He writes: " In contact dipping birds flew close to the surface, wings held back as if to hover, sometimes touching the surface with outstretched feet. Head and neck were plunged down several inches into the water. Forward momentum was regained by vigorous wing beats and foot paddling. Usually when a fish was caught it was eaten without interrupting flight although birds stopped on the surface occasionally, presumably to swallow heavy prey." Such behaviour is commonly used by *bulleri* flocks working areas where predatory fish have forced small sprats to the surface. On 8 January 1973, for example, a flock of 3000 *bulleri* was seen offshore from Aorangi working systematically into the wind around a maelstrom of fish, gathering small prey from the surface in the manner described above, before wheeling back in order to repeat the process. On other occasions the birds appeared not to be catching fish, but in the words of Jenkins (1974), " collecting the remains of the banquet which is being enjoyed by the biggest predatory fish."

Buller's Shearwaters also take prey by surface feeding. In light airs birds abruptly descend to alight on the water and, with their wings held half open, lunge this way and that with their long necks to capture prey. Those observed from only a metre or two away were snatching crustaceans from the water. Salps and jellyfish are also eaten.

Of 30 regurgitations from birds caught on the breeding grounds between October and January, 23 (76.6%) were composed solely of the euphausiid *Nyctiphanes australis* and the rest were a mixture of small fish flesh and euphausiids. The size class of the crustaceans was remarkably uniform (mean 12.9 mm $\pm$ 0.1 mm, range 8.9-17.1 mm; n = 5112). Regurgitations over the same period from the much smaller Fairy Prion yielded the same food in the same size range (mean 12.8 $\pm$ 0.1, range 8.9-16.3 mm; n = 733). The two species must therefore have been taking the prey abundantly available rather than being selective. At other times of year, their foods may well be quite different.

The crustaceans had been ingested just before the birds came ashore. For example, the heaviest *bulleri* at 499 g (Table 4) was caught at 0342 h on 19 January 1973. The bird's bill, head and feet were still wet with sea water, and it regurgitated 59 g of barely dead *Nyctiphanes*. This bird, like several others, was presumed to be a failed breeder visiting the islands briefly before the morning departure.

Nearly all the regurgitated euphausiids were intact. That the Buller's Shearwater's superbly adapted grasping and chopping beak should admit such small soft organisms without even dislodging their

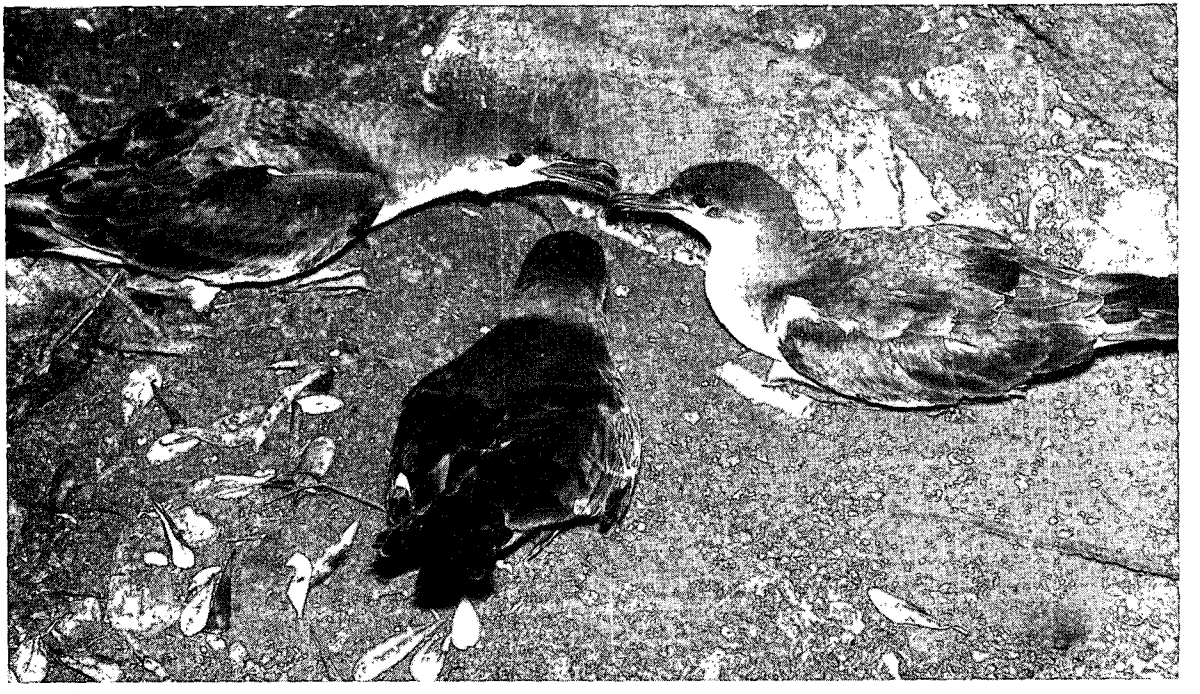

FIGURE 4 — A trio of unemployed birds howling together. Such birds sometimes gather piles of twigs near them, a ritualistic nest-building.

eye-stalks shows how deftly the birds can retrieve small items from the water.

THE FUTURE

On the Poor Knights, *bulleri* is an aggressive coloniser. From the low hundreds in 1938 its numbers on Aorangi have risen so greatly that in 1981 their numbers were roughly 200 000 (Bartle 1968; pers. obs.). This extraordinary rate of increase has probably been largely due to immigration from Tawhiti Rahi and has been at the expense of other petrels, including Grey-faced Petrels and Fluttering Shearwaters *(Puffinus gavia)*. In late November 1940, Wilson (1959) reported from Aorangi that not only were Fairy Prions " breeding in good numbers in crevices in the rocks " but also that " The most common of the other petrels were *gavia,* a species with extraordinary raucous cries, which filled the air at night on their homecoming, and *macroptera,* mostly either ready to fly or already flown." A single pair of *macroptera* seen courting on the ground by J. A. Bartle in 1965 remained the only positive recent Aorangi record of the species until a visit by Paul Sagar and others between 30 April to 9 May 1983, when about a dozen birds were seen in aerial courtship flights or were captured on the ground in Puweto Valley. Whether these birds were visiting or are actually breeding on Aorangi is not known.

Fluttering Shearwaters also suffer. Eleven burrows of *gavia* that were near the outfall of Puweto Stream in 1964 were all occupied by *bulleri* in 1975. Six chicks of Allied Shearwater *(Puffinus assimilis)* raised by this winter-breeding species are also known to have been evicted by *bulleri* seeking territory. A dead adult Sooty Shearwater found in a burrowed area near the summit of Aorangi in November 1963 is the only recent record of *griseus* from the island. Now occupied by *bulleri* only, the site may have been used in the past by Sooty Shearwaters. A single breeding pair of *griseus* was found on Tawhiti Rahi in December 1958 by Kinsky & Sibson (1959), who believed that " the aggressiveness of *bulleri* is the reason for the scarcity of other breeding petrels on this island."

Fairy Prions have fared better than most, largely because they now nest in small crevices, bound on all sides by rock, that *bulleri* cannot get into. Prions occupying a nest with a soil wall or floor, however, run the risk of having it enlarged and their nest contents thrown out (Harper 1976). The Buller's Shearwater is thus a successful competitor for nest space on the Poor Knights Islands. Provided food does not become limiting, it may soon need more nest space, and so other islands such as the Three Kings and the Hen and Chickens may soon be visited by colonists. The effect of this on the small population of Pycroft's Petrel at Hen Island is a matter of concern.

Further studies could be made on the following topics:

1. Information on the migratory pathways of *bulleri* is very scant. The whereabouts of feeding areas important to the species, both in

New Zealand waters and beyond, needs to be known, particularly if such areas are exposed to large-scale commercial fishing or frequent oil pollution.

2. The foods of *bulleri* are largely unknown. Shoaling fish, squid, and crustaceans are likely prey, but detailed and quantified accounts are needed of the bird's diet throughout the year. Means are available for harmlessly flushing out contents of the proventriculus.

3. More information is needed on most aspects of breeding biology of *bulleri,* but study is not easy because incubating birds desert readily. The chick period from hatching to fledging needs study, particularly the composition and frequency of meals.

4. A census of the breeding population of *bulleri* can probably be done on Aorangi; but on Tawhiti Rahi, the number of burrows is too great and too many would be destroyed in a full census.

Despite the well-known risks of a species breeding in only one place, the future for the Buller's Shearwater looks promising, especially if the islands continue to be free of rats.

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P. C. HARPER, *Department of Extension Studies, University of Canterbury, Christchurch 1*

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SHORT NOTE

PREDATION OF GOLDFINCH BY NEW ZEALAND KINGFISHER

The predation of an adult male Goldfinch *(Carduelis carduelis)* by a New Zealand Kingfisher *(Halcyon sancta)* was observed on 24 July 1981 at Pukepuke Wildlife Management Reserve.

The Kingfisher was perched on a cabbage tree overlooking a patch of beggar's ticks *(Bidens frondosa)*, where a small flock of Goldfinches was feeding. At my approach, the finches took flight, and at the same instant the Kingfisher swooped down and caught a male in flight. Death was almost instantaneous with the Goldfinch struggling and squealing for about two seconds before going limp. The Kingfisher took its prey back to the cabbage tree, where it repositioned it in its bill and then flew out of sight.

From the position of the Kingfisher's perch over the feeding finches, it was almost certainly watching them, waiting for an opportunity to take one.

ANDREW GRANT, *Wildlife Service, Pukipuki Road, R.D. 11, Foxton*