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Breeding biology of the Black-winged Petrel, *Pterodroma nigripennis*, on Lord Howe Island

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Abstract. The Black-winged Petrel, *Pterodroma nigripennis*, is a recent coloniser of Lord Howe Island, with adults present between late October and early May. Four nests were monitored during both the 1989-90 and 1990–91 breeding seasons. Eggs were laid at the end of December and hatching occurred in mid February after 45.3 ± 0.5 days' incubation (mean ± s.d.). Young (weighing 175.5 ± 8.7 g) fledged in early May, 84.8 ± 0.5 days after hatching and 10.3 ± 1.6 days after feeding stopped. On average, chicks were fed every 2.5 days, with each parent returning every 4.4 days. Provisioning rates remained constant throughout the period of chick rearing. Average meal size was estimated at 32.6 g. Inter-specific competition for nesting burrows with Little Shearwaters, *Puffinus assimilis*, was observed.

Introduction

The Black-winged Petrel, *Pterodroma nigripennis*, is a small gadfly petrel that breeds colonially on subtropical and tropical islands and islets in the south-west Pacific Ocean (Merton 1970, 1984; Jenkins and Cheshire 1982). In contrast to many other Procellariiformes, this species is expanding its breeding range (Klapste 1981; Powlesland 1985) and is a relatively recent coloniser (or recoloniser) of Lord Howe Island. Sub-fossil bones on Lord Howe Island show that this, or a very closely related form, was present in the past (Fullagar *et al.* 1974), but early accounts by local naturalists make no mention of it (Hindwood 1940). Islanders recall hearing the call of Black-winged Petrels occasionally from the 1940s, but it was not until the 1960s that it became well known to them. The species was not confirmed breeding on Lord Howe Island until 1971 (Fullagar *et al.* 1974). Since then, their numbers and breeding range on the island have increased. Several hundred pairs of Black-winged Petrels now breed on Lord Howe Island.

Despite its relatively broad geographic range, the Black-winged Petrel nests only on oceanic islands, many of which are remote; consequently, virtually nothing is known about its breeding biology (Marchant and Higgins 1990). In 1990, four Black-winged Petrel nests were monitored from the time of hatching through to fledging, and the same nests in 1991 from laying through to hatching. This paper reports the results of those studies together with other observations of behaviour at the nesting grounds. Although the data are limited, they provide the first detail regarding many aspects of the species' breeding biology, including timing of the breeding cycle, incubation period, incubation shifts, nestling period, chick growth rates, provisioning rates, meal sizes and the period of starvation before fledging.

Study site

Lord Howe Island (31°33'S, 159°05'E) is a small (1455 ha) volcanic island situated in the Tasman Sea, 570 km east of the Australian mainland. The island, about 10 km long and 2.8 km at its widest point, is dominated by two steep mountains - Mount Lidgbird and Mount Gower - which rise to 777 m and 875 m, respectively, above sea level. The island is roughly crescent-shaped, with the western concave side being bordered by a coral reef 6 km long, enclosing a lagoon about 2 m deep. The main island is surrounded by a number of smaller islets, the most spectacular of which is Balls Pyramid, an eroded stack, 551 m high and 23 km to the south-east of Lord Howe Island.

Islands within the Lord Howe Group support significant breeding colonies of seabirds. Fourteen species breed there: Black-winged Petrel; Providence Petrel, *Pterodroma solandri*; Kermadec Petrel, *Pterodroma neglecta*; Wedge-tailed Shearwater, *Puffinus pacificus*; Flesh-footed Shearwater, *Puffinus carneipes*; Little Shearwater, *Puffinus assimilis*; White-bellied Storm-Petrel, *Fregetta grallaria*; Red-tailed Tropicbird, *Phaethon rubricauda*; Masked Booby, *Sula dactylatra*; Sooty Tern, *Sterna fuscata*; Common Noddy, *Anous stolidus*; Black Noddy, *Anous minutus*; Grey Ternlet, *Procelsterna cerulea*; and White Tern, *Cygis alba.*

Black-winged Petrels breed in small colonies on numerous headlands of Lord Howe Island and on Balls Pyramid, nesting in burrows typically 0.4–1.0 m long. The study nests were close together within a small colony of about 20 nests on the headland at the northern end of Blinky Beach, Lord Howe Island. The burrows were all in rocky basaltic soil and short enough to enable easy access to the chicks. In softer, sandy soil (such as that along Neds Beach) the burrows were longer, and often angled, making access to the chicks difficult.

Methods

1989-90 breeding season

Activity at the colony was noted throughout the breeding season (October 1989 to May 1990 inclusive). In January, four accessible nests were located. Each nest contained an adult sitting on an egg. These nests were then inspected daily (with some omissions, see Fig. 1), at varying times of day, until all young fledged (9 May 1990). At each

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inspection the chick was removed from the burrow, placed in a cloth bag and weighed to the nearest gram using a Salter 100-g or a Pesola 300-g balance. Increases in mass were presumed to be associated with the chick having been fed by one or both parents. The data collected were used to assess feeding frequency, meal sizes, chick growth rates, the time of fledging and the duration of the nestling period. Chick weights that exceeded the range of the balance (n = 4) were recorded as >300 g. These imprecise data were used to assess feeding events and determine feeding frequency but were omitted from the analyses of mean weight gain or loss.

1990–91 breeding season

In December of the following breeding season (1990-91) the same burrows were inspected daily for the presence of an egg or breeding adult. Newly laid eggs were removed from the burrow, weighed and returned. These nests were monitored daily until the eggs hatched, providing details of the date of laying and the period of incubation.

Results

Observations at the colony

Black-winged Petrels breed colonially on Lord Howe Island during the austral summer. Adults are present from late October to early May. Initially they are quiet, but by late November the colony is noisy by day and night, with birds calling loudly while performing spectacular aerobatic courtship flights until egg laying commences in late December. Non-breeding adults continue the close-contact chases and aerial calling until the end of March.

Most breeding birds that return to feed their chicks come ashore at night, typically arriving shortly after dusk. Throughout the day, however, small numbers of birds can be seen returning to the colony. In marked contrast to their noisy courtship flights, birds returning to feed chicks fly swiftly and silently to their burrows.

Egg laying, incubation and hatching

The burrows studied were about 0.5 m long. Nest chambers were lined with fresh green leaves and litter. A single white egg was laid in each nest at the end of December (mean, 31 December, n = 4; Table 1). Mean (±s.d.) egg mass shortly after laying was 33.8 ± 0.5 g (range 33-34 g, n = 4; Table 1). In 1990, all eggs hatched on 13 February (Table I). In 1991, hatching occurred on 13–15 February (mean = 14 February, n = 4; Table 1). Mean incubation period was 45.3 ± 0.5 days (range = 45–46 days, n = 4; Table 1). The mean weight of adults was 172.3 ± 9.3 g (range 162-180 g, n = 3). Observations of changeovers by incubating birds, as evidenced by disturbed twigs placed across the burrow entrance, suggested incubation shifts of 10–12 days' duration.

Chick growth and fledging

Chick growth rates are shown in Fig. 1. The curve can be described by the following polynomial regression:

$$y = -0.007x^3 + 0.0348x^2 + 4.0574x + 25.059 \quad (r^2 = 0.9644).$$

Initial mass and fledging mass of the four individuals were relatively similar; however, there was considerable variation in growth rate between individuals, as evidenced by the large standard deviations about the mean for all ages between 10

Table 1. Breeding parameters of Black-winged Petrels on Lord Howe Island

	Nest 1	Nest 2	Nest 3	Nest 4	Mean
Laying date (1990–91)	31.xii.1990	31.xii.1990	30.xii.1990	30.xii.1990	31.xii.1990
Egg mass (g)	33	34	34	34	33.8
Hatching date (1990–91)	15.ii.1991	14.ii.1991	13.ii.1991	13.ii.1991	14.ii.1991
Incubation period (days)	46	45	45	45	45.3
Hatching date (1989-90)	13.ii.1990	13.ii.1990	13.ii.1990	13.ii.1990	13.ii.1990
Fledging date (1989–90)	9.v.1990	8.v.1990	9.v.1990	9.v.1990	9.v.1990
Nestling period (days)	85	84	85	85	84.8
Maximum chick mass (g)	284	278	274	>300	>284
Fledging mass (g)	182	168	168	184	175.5
Date of last feed	30.iv.1990	28.iv.1990	30.iv.1990	26.iv.1990	29.iv.1990
Duration between last feed and fledging (days)	9	10	9	13	10.3
Mean (±s.d.) daily weight loss (g)	8.9 ±7.2	13.6± 10.2	9.6 ±9.4	14.8 ±9.6	11.6 ±9.3
Mean (±s.d.) daily weight gain (g)	18.3 ±9.7	20.1 ± 11.8	23.0 ± 17.4	22.8 ± 14.0	21.0± 14.1
Approximate average meal size (g)	27.2	33.7	32.6	37.6	32.6
Number of days fed (out of 54 records)	21	24	23	20	22
Number of days not fed (out of 54 records)	33	30	31	34	32
Probability that neither parent feeds chick[A]: $(1 - P)^2$	0.6111	0.5556	0.5740	0.6296	0.5926
Probability that a parent does not feed chick[A]: (1 — P)	0.7817	0.7454	0.7577	0.7935	0.7696
Probability that a parent does feed chick[A]: (P)	0.2183	0.2546	0.2423	0.2065	0.2304
Probability that both parents feed chick on same day[A]: (P^2)	0.0476	0.0648	0.0587	0.0426	0.0535
Presumed double feeds	3	4	3	2	2.9
Frequency of feeding by a single parent (days)	4.6	3.9	4.1	4.8	4.4

[A]Probability of being fed or not fed on any one particular day.

and 75 days. Chicks reached a maximum weight of at least 274 g before shedding 36–40% of this mass to fledge at 168–184 g (mean = 175.5 ± 8.7 g, n = 4; Table 1).

Young fledged on 8-9 May (mean = 9 May, n = 4; Table 1). The mean nestling period (hatching to fledging) was 84.8 ± 0.5 days (range = 84-85 days, n = 4; Table 1). No weight increases were recorded after 30 April, indicating that parents did not feed their chicks after this date (Table 1). The duration between the last feed and fledging averaged 10.3 ± 1.6 days (range = 9-13 days; Table 1).

On 10 April 1990, the chick from Nest No. 3 was ousted from its burrow by a pair of Little Shearwaters intent on using the burrow for their winter breeding. Thereafter, the petrel chick was sometimes found inside the burrow and sometimes outside it. On 4 May it appeared to have been evicted with considerable force, suffering a laceration to its head. The chick survived this ordeal and fledged, apparently in good health, on 9 May 1990. The Little Shearwaters continued to use the burrow, the female laying an egg on 1 July 1990.

Provisioning rates

Each of the four petrel nests was inspected on 71 of the 85 days between hatching (13 February 1990) and fledging (9 May 1990). Between hatching and 30 April (the date after which there were no further feeds) there was a total of 54 days for which there was sufficient data to calculate the daily weight change for each of the four chicks. Data were grouped according to whether the weight change was negative (including zero) or positive. Weight increases of the nestling were presumed to be associated with it having been fed by one or both parents. The mean daily weight gain, the net increase in mass as a result of food intake, was 21.0 ± 14.1 g (range = 2–72 g, n = 86). The mean daily weight loss, an estimate of the mass lost through defecation and respiration when no feeding has taken place, was 11.6 ± 9.3 g (range = 0–45 g, n = 124). The summation of mean weight gain and mean weight loss provides a crude estimate of average meal size: 27.2-37.6 g per individual, or 32.6 g overall (Table 1). However, due to (1) infrequent weighings, (2) the possible non-inclusion of small meals, and (3) systematic bias caused by weight loss through excretion and respiration, this figure should be regarded as an approximation only. Daily weight increases of more than 40 g are likely to have been associated with instances when both parents returned with food during the same night. As nests were visited only once daily it was not possible to determine the time at which parents returned to the colony to feed their chicks, nor the proportion of parental visits that occurred during daylight hours.

On average, each chick received food on 22 (41%) of the 54 days for which data were available (range = 20-24, n = 4; Table 1), or approximately one feed every 2.5 days. Typically, chicks were fed every second or third day; only occasionally did they go without food for four days or longer. There was no evidence to suggest that the frequency of feeding changed during the period of chick rearing (Fig. 2).

The frequency of feeding by each parent can be calculated using the following methodology (after Ricklefs 1984). If the probability of a particular parent feeding its chick on any particular night is P, then the probability that it does not feed it is (1 - P). Assuming that members of a pair feed their chick independently, it follows that the probability of neither parent feeding the chick is $(1 - P)^2$, which can be estimated from the observed frequency of zero or negative mass increments. P (the probability of being fed) and P^2 (the probability of being fed by both parents) can then be calculated (Table 1). The mean probability that a parent would feed its chick on any particular night was 0.2304 (range 0.2065-0.2546; Table 1); thus, the average frequency of feeding by a single parent was every 4.4 nights (range = 3.9–4.8, n = 4; Table 1).

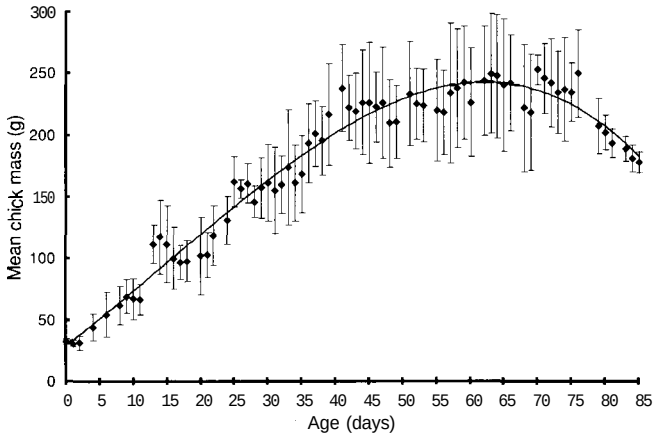

Fig. 1. Growth of Black-winged Petrel chicks (mass) from hatching to fledging. Data are means ± standard deviation (n = 4) and the fitted curve is a polynomial regression ($y = -0.007x^3 + 0.0348x^2 + 4.0574x + 25.059$, $r^2 = 0.9644$).

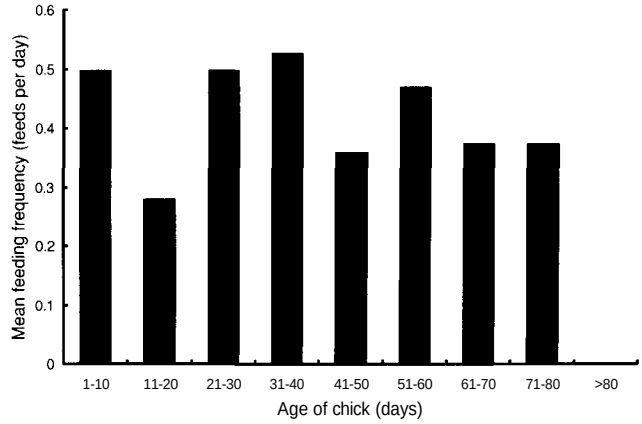

Fig. 2. Provisioning rates during each 10-day period between hatching and fledging (Day 84/85) for Black-winged Petrel chicks.

Discussion

Although activity at the colony tended to peak after dusk, Black-winged Petrels on Lord Howe Island were active both diurnally and nocturnally. Not all colonies of this species are diurnal, and most other burrowing *Pterodroma* are exclusively nocturnal while over land. The time and level of daily activity at a petrel colony is generally governed by the activities of predators (Watanuki 1986), with many species relying on the cover of darkness for protection. The high level of activity by Black-winged Petrels during daylight seemingly reflects the absence of diurnal avian predators on Lord Howe Island. However, on islands in northern New Zealand, which also lack diurnal predators, Cook's Petrel, *Pterodroma cookii*, and Pycroft's Petrel, *Pterodroma pycrofti*, are strictly nocturnal (K.-J. Wilson, personal communication).

With the exception of some diurnal activity at the colony site, the breeding biology and general behaviour of Black-winged Petrels on Lord Howe Island are similar, in most respects, to those of other Procellariiformes. The incubation period of 45 days, and the nestling period of 85 days, are similar to those of other petrels of comparable size (see Warham 1990). The Bonin Petrel, for example, weighs about 180 g and has an incubation period of 48.7 days and a nestling period of about 82 days (Pettit *et al.* 1982). An incubation shift of 10-12 days is similar to that of other gadfly petrels, being among the longest (per unit body mass) of any Procellariiformes (see Warham 1990). The 10-day period of fasting immediately before fledging is similar to that of other gadfly petrels, such as the Gould's Petrel, *Pterodroma leucoptera* (9–11 days: Priddel and Carlile 2001) and the Chatham Island Petrel, *P. axillaris* (9-14 days: Gardner 1999). The data suggest a high rate of breeding success (100%) but, in view of the limited sample size, this figure should be interpreted cautiously.

Among the small number of nests studied, breeding was highly synchronous. During the 1989-90 breeding season, all four eggs hatched on the same day (13 February), and the young all fledged within a day of each other (8-9 May). During the 1990–91 breeding season, all four eggs were laid within the space of two days (30–31 December), and they all hatched within two days of each other (13-15 February). Such tight synchrony has not been reported for any other species of *Pterodroma* and is probably a consequence of the small sample size and close proximity of burrows. Data on the breeding synchrony of Black-winged Petrels elsewhere is lacking.

Black-winged Petrels are present on Lord Howe from October to May; after which they appear to disperse into the waters around Fiji (Clunie *et al.* 1978), Tonga (Jenkins 1980) and the central Pacific Ocean (Pratt *et al.* 1987). At sea, Black-winged Petrels feed singularly or in small groups (Jenkins 1971; Klapste 1981) and are thought to feed mainly on cephalopods and prawns (Imber in Marchant and Higgins 1990). However, no detailed information is available on diet or the foraging areas used by breeding birds. Long incubation spells and absences of 4-5 days by parents feeding young in the nest suggests that they forage considerable distances from their nesting grounds on Lord Howe Island. Comparative data from other colonies are lacking.

Black-winged Petrels are vulnerable to predation by cats and rats (Merton 1970; de Ravin 1975; Klapste 1981). On Lord Howe Island, they may also have been sensitive to the impact of feral pigs and goats (Fullagar and Disney 1975). (Pigs were eradicated from Lord Howe Island in 1979. Feral goats were almost eradicated in 2000, and only a few individuals remain.) Inter-specific competition for nesting burrows, however, had not previously been identified as an issue for the Black-winged Petrel. Repeatedly ousted from its burrow by a pair of Little Shearwaters during the last third of the nestling period, the young Black-winged Petrel survived and fledged successfully despite sustaining a severe wound to the head. Similar inter-specific competition for nest sites has usually resulted in the petrel chick being killed outright. Young Chatham Island Petrels, for example, are often killed by Broad-billed Prions, *Pachyptila vittata*, prospecting for burrows (Gardner and Wilson 1999), and young Bermuda Petrels, *Pterodroma cahow*, are readily killed by competing Red-tailed Tropicbirds (Wingate 1978; Sullivan *et al.* 2000). The interaction between Black-winged Petrels and Little Shearwaters, both threatened species (New South Wales Government 1995), on Lord Howe Island warrants further investigation.

While many other gadfly petrels have declined in numbers in recent years (Birdlife International 2000), the Black-winged Petrel has been expanding its range westward across the south-west Pacific. The species was once known to breed only in the Kermadec group of islands (Merton 1970) but within the last century it has colonised (or recolonised) Lord Howe Island, Philip Island off Norfolk Island (Tarburton 1981), and Three Kings Island (Turbott 1951), Portland Island (Eagle 1980) and the Chatham Islands of New Zealand (Merton 1984). The species is also purported to have attempted to nest on Norfolk Island (Hermes *et al.* 1986) and to have been prospecting for breeding sites along Australia's eastern seaboard (Kikkawa and Boles 1976; Holmes 1977). This expansion has occurred despite the species being susceptible to the adverse effects of human settlement and introduced predators.

Twenty-one species of *Pterodroma* are currently regarded as threatened (Birdlife International 2000). Our ability to conserve these species may be enhanced by an understanding of how the Black-winged Petrel has managed to expand its range during the current global trend of declining marine resources and increasing degradation of marine environments. The key lies in identifying those specific traits responsible for the petrel's success. This study found no particular

aspect of the bird's breeding biology to be dissimilar to that of other members of the genus for which data are available. More extensive, longer-term studies are needed, particularly in relation to philopatry. Procellariiformes are generally highly philopatric (Warham 1996) but, for Black-winged Petrels to colonise distant islands, at least some individuals within the population must exhibit low philopatric tendencies. Information regarding the philopatric behaviour of Black-winged Petrels, on Lord Howe Island and elsewhere, is currently lacking.

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