

SHORT NOTE

A new record of marsh crake (*Porzana pusilla*) from the Waikato

MARTIN R. DAY

9 Conrad Place Cambridge, New Zealand.

mday@wave.co.nz

BETTY H. SEDDON

11 Grey Street Cambridge, New Zealand.

The marsh crake (*Porzana pusilla*) inhabits the 3 main islands of New Zealand (Heather & Robertson 1996) and while it is sparsely distributed throughout, it is not considered rare. Distribution maps for the species (Bull *et al.* 1985; Heather & Robertson 1996) do not record marsh crake in the Waikato. Whether this indicates small numbers, difficulty in observing a secretive species, a lack of observers, or a combination of these factors is not known. We know of only 1 published record of marsh crake in the Waikato area since the 1970s, a bird found dead at the Whangamarino River bridge on 1 Feb 1989 (Nieuwland 1991). However 1 was seen and photographed by a New Zealand Department of Conservation officer (A. Bauke, pers. comm.) at Lake Ngaroto in June of either 1987 or 1988.

In June 2000, we surveyed Lake Ngaroto, the largest of the Waikato peat lakes, about 5 km northwest of Te Awamutu. On 27 June 2000 at about 1400 h, a small rat-sized animal scuttled from under the boardwalk bordering the lake and disappeared into the predominantly willow (*Salix* spp.) scrub. When we returned c.15 min later it was observed again and identified as a marsh crake (*Porzana pusilla*), on the basis of the bird's small size, and the contrast between the brown upper surface streaked with black and white and the black and white barring under the tail. A 2nd bird was also seen, but whether the birds were a pair was not determined. On the following day, 28 June, the birds were ob-

served by several OSNZ members, who confirmed our initial identification. Also on 28 June, 2 spotless crakes (*Porzana tabuensis*), which had not been seen the previous day, were also noted. On 30 June, MRD saw single birds of both species feeding about 1 m from each other, with no apparent interaction. Marsh crake will answer taped calls of spotless crake during the breeding season, and would appear to be quite territorial at this time (Kaufmann 1987). Further monitoring on 3 August 2000 by MRD gave the following numbers of birds spread over c.1 km of the lakeshore surveyed: marsh crake, 6 birds in 3 groups of 2; spotless crake, 4 birds in 2 groups of 2. As would appear normal for crakes, all birds seen so far have been under shelter, either willow scrub or the boardwalk. Although there are a few anecdotal records of sightings of marsh crake in the Waikato, this appears to be the first verified sighting of live birds.

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Breeding, survival, and recruitment of Chatham Island pigeon (*Hemiphaga chathamensis*)

I.A. FLUX

Science & Research Unit, Department of Conservation, P.O. Box 10-420, Wellington, New Zealand
iflux@doc.govt.nz

R.G. POWLESLAND

Science & Research Unit, Department of Conservation, P.O. Box 10-420, Wellington, New Zealand

P.J. DILKS

Science & Research Unit, Department of Conservation, Private Bag, Christchurch, New Zealand

A.D. GRANT

Canterbury Conservancy, Department of Conservation, Private Bag, Christchurch, New Zealand

Abstract The Chatham Island pigeon or parea (*Hemiphaga chathamensis*) is an endangered species of pigeon endemic to the Chatham Islands. Effective conservation management of the Chatham Island pigeon required an understanding of its ecology and identification of the causes of decline. We studied the pigeon in their last remaining stronghold; the south-west of Chatham Island, New Zealand, between July 1991 and December 1994. We describe the nesting behaviour, nesting success, and the dispersal, survival, and recruitment of juveniles. The study was confounded by the lack of information on predator numbers or outcomes of pigeon nests from before the start of predator control activities within and adjacent to our study area. Despite a previously reported decline in pigeon numbers up until the early 1990s, during this study there was a 3-fold population increase, and only a low level of predation by possums and rats. Other than predation, no factor which might previously have limited the pigeon population was identified. We assume that the trapping and poisoning of pest-mammals since 1989, has been sufficient to allow the population of Chatham Island pigeon to recover.

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INTRODUCTION

The Chatham Island pigeon or parea, *Hemiphaga chathamensis*, occurs only in the Chatham Islands, 860 km east of New Zealand. *Hemiphaga* is an endemic, monotypic, New Zealand genus of large (500-900 g) fruit pigeons whose relationship to other fruit pigeons is problematic (Goodwin 1983). Three taxa have been described, of which 2 are extant; the kereru (*Hemiphaga novaeseelandiae*) is widespread, though probably declining, throughout the mainland of New Zealand, while the Chatham Island pigeon is considered endangered (Bell 1986).

Chatham Island pigeons remained common well into the period of European and Maori settlement during the nineteenth century (Travers & Travers 1872), but by 1975 were rare and largely confined

to the more forested southern area of Chatham Island (Merton & Bell 1975)(Fig. 1). In 1989 the population was estimated at 40-45 individuals (Grant 1990), though Pearson & Climo (1993) consider that this was an "optimistic" figure. The decline has been attributed to widespread clearance and degradation of the forest habitat by humans and domestic stock, coupled with predation by humans and introduced mammals (Grant 1990). Known, or potential, predators of the pigeon that have been introduced to the islands include cats (*Felis catus*), 3 species of rats (Pacific rat, *Rattus exulans*; ship rat, *R. rattus*, and Norway rat, *R. norvegicus*), brushtail possums (*Trichosurus vulpecula*), pigs (*Sus scrofa*), and weka (*Gallirallus australis*).

Agricultural development on the islands has increased the area of open habitat. Consequently, a predator of pigeons, the Australasian harrier (*Circus approximans*), which was considered rare on

Chatham Island in 1872 (Travers & Travers 1872), is now common. Given this predation pressure, concern was expressed over the plight of Chatham Island pigeons by Grant (1990) and Pearson & Climo (1993). To aid management of the pigeons Grant (1990) recommended research into their biology and ecology, and the relative impacts of predators on their breeding and survival.

Our study aimed to determine causes of decline and to investigate at which life-history stage(s) reduced survival contributed most to the decline. It became clear during the 3 years of this study, that the pigeon population was no longer declining. Breeding success, juvenile recruitment, and adult survival were all high and the population increased 3-fold in that time (Grant *et al.* 1997). We suggest that this may be attributed to the success of a predator-control programme, aimed at cats and possums, which began in this area during 1989 and was expanded throughout the pigeon habitat during the course of our study (Imber *et al.* 1994; Grant *et al.* 1997).

This paper, therefore, describes the breeding biology and survival of the Chatham Island pigeon between 1991 and 1994. Information that we present on nesting requirements may be used to encourage landowners to protect further lands by fencing and removal of stock. The fledging rate will provide a baseline from which to determine the success of future management of the species. Related topics, such as distribution, abundance, and diet and its relationship to breeding have been presented elsewhere (Grant *et al.* 1997; Powlesland *et al.* 1997).

STUDY AREA AND METHODS

Study area

The study area, (c.400 ha), was in south-west Chatham Island (Fig. 1) and included the catchments of the Awatotara Creek, Tuku-a-tamatea River, Kawhaki Creek, and Waipurua Creek to about 3 km inland. The main habitats of Chatham Island pigeon in the Awatotara and Tuku-a-tamatea catchments were partially fenced in 1985 to exclude grazing animals. During 1992-93 the fenced area was extended to include more habitat (Grant *et al.* 1997). A mosaic of regenerating low forest, scrub, fern, and rough grassland (Powlesland *et al.* 1997) now covers areas within the fence.

Predator control

A line of predator control traps was set periodically, from 1989, to protect Chatham Island taiko (*Pterodroma magentae*) nesting on the margins of the pigeon study area (Imber *et al.* 1994). The trapping may have reduced predator densities within the pigeon habitat. From 1992/93, brodifacoum bait-

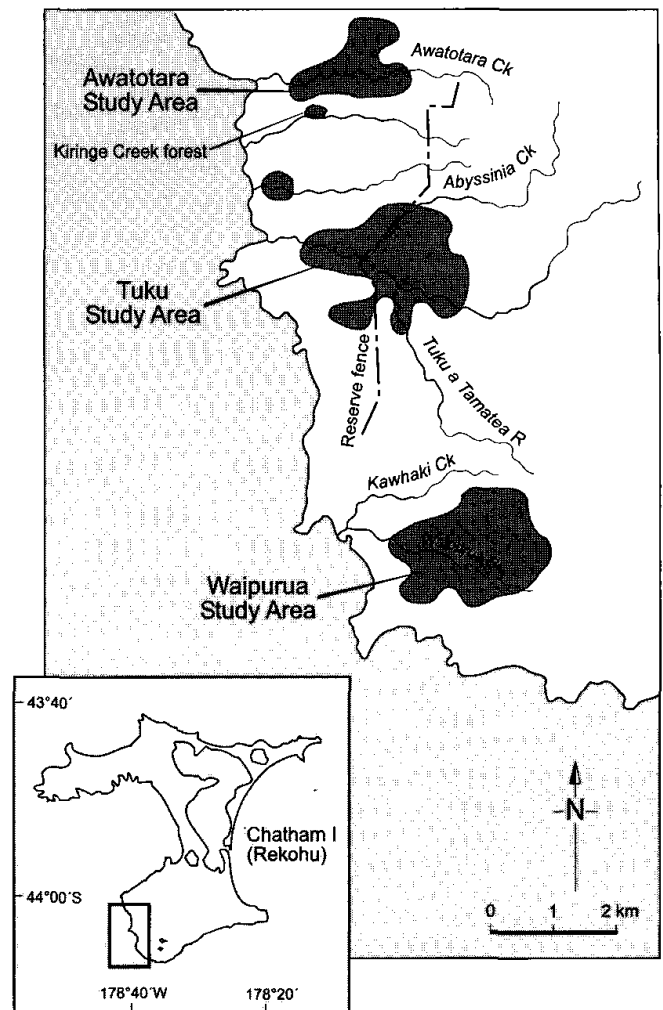


Fig. 1 Chatham Island, showing locations of Chatham Island pigeon (*Hemiphaga chathamensis*) study areas (shaded).

stations set throughout the pigeon breeding area and baited 6-monthly (Grant *et al.* 1997) kept possums at very low densities ($<1\text{ha}^{-1}$) over most of the study area for the remainder of our study (Grant *et al.* 1997). During 1991 we protected all nests. Six rat traps and 6 bait stations containing brodifacoum bait were spaced evenly within a 25 m radius of each nest. The following year we protected only half the nests located, and from 1993 on we did not protect nests.

Capture and marking

Three-week field trips were made 4 times each year from 1991 to 1994, with additional trips when pairs were breeding. Over this time 27 adult pigeons were captured using mist-nets and 37 nestlings were marked shortly before fledging. Captured birds were weighed, then individually marked with numbered metal leg-bands and coloured leg-flags (jesses), of nylon-reinforced PVC. No sexual dimorphism was evident visually or in the weights recorded. Sex was assigned only after observing

courtship, nest-changeovers, or copulations. Nine adults and 6 nestlings were also fitted with radio transmitters using a back-mounted harness design (Karl & Clout 1987).

Monitoring of adults and nests

During each field trip we searched for pigeons to determine survival, breeding activity, and the presence of juveniles. Radio-tagged individuals were located using radio-telemetry. Others were detected by searching suitable habitat within and beyond the study area, where particular foods were abundant. All day watches from hilltops identified where birds were active. The rate of display flights provided an indication of breeding activity and careful observation of these flights was often useful in locating pair territories and nest sites. Individually colour-jessed birds could be identified from considerable distances and all sightings were logged.

For up to 8 months after fledging, juvenile pigeons could be readily distinguished from adults by their dull, brown-tipped bill, dull feet, dark eyes, and a less well-defined border between the dark chest and white breast feathers (Powlesland *et al.* 1994; Mander *et al.* 1998).

Nests were located by observing pairs, noting nest changeovers or carriage of twigs, and following individual birds or locating birds with radio-transmitters (Powlesland *et al.* 1997). We recorded a description of each nest site, including location, the species of the supporting plant, vegetation type, nest height vertically above ground, canopy height above the nest, and an estimate of the vegetation cover (proportion of sky concealed) directly above the nest. All possible nests, and where possible their contents, were examined at least weekly to determine their fate. In addition a sample of nests at different stages of the breeding cycle was observed from dawn to dusk to record times when adults changed over at the nest and when they fed chicks.

RESULTS

Gender roles

Gender was not independently determined for most pigeons during the course of this study. However, we determined that 1 member of each study pair consistently incubated at night and the other by day. We assume throughout this paper that day-incubating birds from all pairs were male and night-incubating birds were female. Our observations of nest building (below) support this assumption in that gender roles were consistent with those described for other pigeon species (Goodwin 1983). Confirmation of our gender assignment was obtained for 3 pairs from their positions during copulations.

Nests

Between 1991 and 1994, 101 active nests were located. Initially, both members of pairs collected material and built nests. However, when nest building intensified, males collected most of the material while females accepted and arranged twigs at the nest. Twigs up to 50 cm long were used, of tarahinau (*Dracophyllum arboreum*), karamu (*Coprosma chathamica*) or, less commonly, kopi (*Corynocarpus laevigatus*), supplejack (*Ripogonum scandens*), and matipo (*Myrsine chathamica*).

Twelve nests were observed during site selection or early building stages. Pairs visited potential nest sites together, frequently displaying and breaking off and carrying twigs. Nest building over 1-3 days established the basic nest structure that was added to sporadically over the following 2-12 days before egg laying.

Nests were built between ground level and 10.1 m above ground, (mean 3.9 m, SD = 2.2 m, $n = 101$). Two nests were built on the ground and a further 5 were within 1 m of it. Average canopy height above nests was 5.6 m (SD = 2.1 m, range 1.1 - 10.5m, $n = 101$), thus most nests were well within the forest canopy or in understorey vegetation. Nests were usually on firm bases such as shallow-branched forks, near-horizontal trunks, dense clusters of twigs, overlapping bases of tree-fern fronds, tangles of supplejack vines, or combinations of these. Most (89%) of nests were robust platforms of twigs with a shallow bowl, whilst the remaining 11% were insubstantial structures. Nests were commonly in valley bottoms (41%) or lower slopes (55%) in dense, mixed broadleaf and tree-fern vegetation. Fourteen plant species provided nest sites either individually or in combination. Site details were recorded for 98 nests, 20.4% were in *Dicksonia* tree-ferns, 13.3% in tangles of tree-fern (*Dicksonia*) fronds and supplejack vines, 15.3% in matipo, 10.2% in kopi, 9.2% in hoho (*Pseudopanax chathamica*), and 9.2% in tarahinau. Parea were rarely seen feeding in groves of *Dicksonia* tree ferns, yet 34% of nests were in such sites. Hardwood trees supported 56% of nests, and a further 9% were in bracken, low scrub, or on the ground. In general, Chatham Island pigeons selected sites concealed by dense tangles of overhead vegetation and only 7% of nests had little (<60%) cover overhead.

Pairs were territorial and favoured particular parts of their territory for nesting. Nests were often situated within 100 m of previous nests but reuse of nest sites was uncommon (14%, $n = 63$ nests, where a pair's previous nest site(s) was known). Only on 3 of the 9 such instances did old nest material remain at the site as a base on which new nesting material was arranged.

Eggs

Parea eggs were smooth, oval and matt white (length, $\bar{x} = 50.7$, $SD = 1.96$, $n = 13$, range 46 – 53; width, $\bar{x} = 34.3$, $SD = 1.03$, $n = 13$, range 32.5 – 35.5). The fresh weight of an egg was estimated to be 31.9 g [weight = $k \times \text{length} \times (\text{breadth})^2 / 1000$, with $k = 0.535$, averaged from data on the Columbidae; Robertson (1988)] which represents 4.0% of mean adult weight (789 g, $n = 38$). Weights of known males and females did not differ significantly (authors' unpubl. data). Three intact eggs, which had been incubated for 5–10 days, were found on the ground below nests and weighed 32, 31, and 30 g respectively. Four eggs that failed to develop and had been abandoned after full-term incubation weighed 29.0, 28.1, 27.0, and 26.4 g. Clutch size was 1 in all 17 nests where the egg was seen, and brood size was invariably 1 ($n = 73$).

Fifteen of 22 pairs (68%) were actively nest-building up to 4 days before the known or estimated date of laying (as determined by hatch date), and at least 5 pairs were intensively nest-building up until the date of laying. Seven pairs (32%) had pre-laying periods of 6–14 days from the completion of intensive nest-building activity until the egg was laid. In the pre-laying period, females were found sitting on nests during the day, and males occasionally brought twigs to the nest. At 2 nests, pair changeovers were observed even though eggs had not been laid.

Incubation and early brooding

For 8 nests where the date of laying was known, incubation began immediately at 5, while at 3 the egg was left for up to 20 min. at a time during the first few days. The incubation period was recorded for 4 nests. Time between start of incubation and first sighting of either eggshell fragments below the nest or a chick was 27, 27, 28, and 29 days.

Seventy-seven nests were observed during incubation. Male pigeons incubated for about 50% of daylight hours, from 0.5–1h before solar midday until 0.5–1h before sunset (Fig. 2). Changeovers were rapid, with the egg exposed usually for less than one min. During incubation and while the chick was being constantly brooded (<10–15 days old) Chatham Island pigeons brought a twig, usually leafy tarahinau, to their nest at changeovers on 69.4% of 62 occasions. There was no difference between the sexes in this behaviour; males brought twigs on 68.7% of occasions ($n = 32$) and females on 70% of occasions ($n = 30$).

Chick rearing

Chicks were brooded constantly until well feathered at about 10–15 days old. Thereafter, brooding was erratic, with chicks left unattended for long

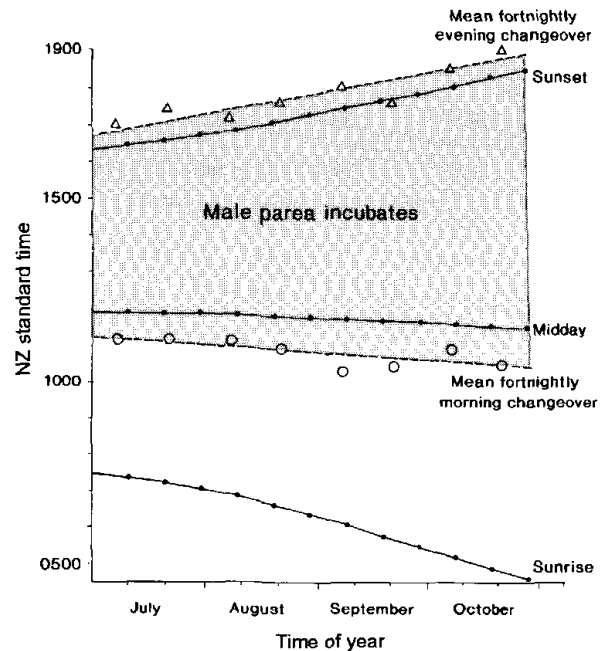


Fig. 2 Period of the day that male Chatham Island pigeon (*Hemiphaga chathamensis*) incubated (shaded) relative to New Zealand Standard Time at sunrise, midday, and sunset during the main nesting months (July–October); $n = 77$ nests.

periods. Nestlings were fed infrequently during the first 2 weeks. One 7-day-old chick was fed only once during the day, and 2 chicks aged 12 and 15 days were each fed twice. A chick 36 days old and another aged 37 days were fed 3 and 5 times respectively, by day. It is not known whether nestlings were also fed at night. The incoming parent usually initiated food regurgitation; chicks encouraged feeding at times by pecking around the adult's bill and neck, flapping wings and emitting low begging calls. Feeding progressed as a series of bouts of regurgitations over 5–20 min.

In their 1st week, chicks were sparsely covered with down. Plumage developed rapidly and by 14 days of age chicks were well covered. Remiges, rectrices, and head feathering were the last to develop. Chicks had no feathering at the base of the bill (i.e. over the forehead and cheeks), which gave the bill an elongated appearance (Mander *et al.* 1998). Feathers developed in this area after a fledgling reached independence. Fledging age was known, to within 5 days, for 20 chicks, which fledged at an average of 46 days (range 36–53 days) though many moved about in the nest tree up to 5 days before. After fledging it became difficult to locate the fledglings. Nevertheless, subsequent sightings of 16 known-age fledglings showed that parents continued to feed them for at least 1 week following fledging. The age at which fledglings

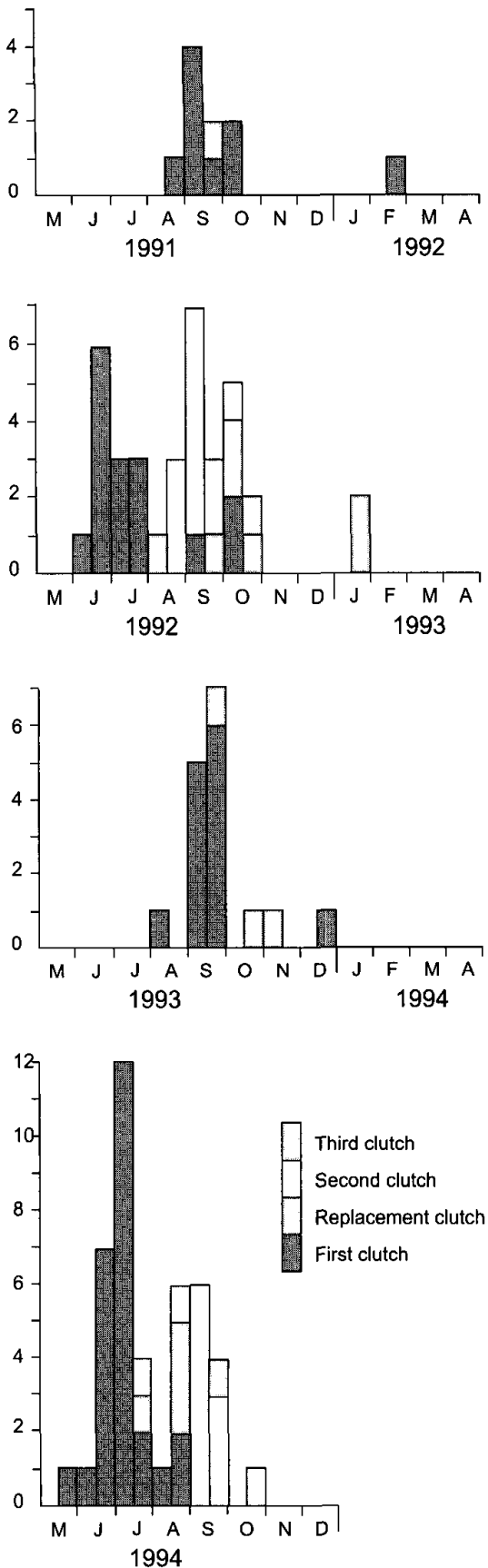


Fig. 3 Fortnightly distribution of egg-laying dates for Chatham Island pigeon (*Hemiphaga chathamensis*) during 4 nesting seasons, from May 1991 to December 1994 (after Powlesland *et al.* 1997). y-axis, no. of pairs; darkest shading, 1st clutch; medium shading, replacement clutch; light shading, 2nd clutch; = "diagonals", 3rd clutch.

reached independence was highly variable, but was usually 52 - 65 days. When pairs did not re-nest, some fledglings were seen with their parents and were occasionally fed by them for up to 179 days. If parents re-nested, fledglings from previous broods were sometimes driven from the territory, but in other instances fledglings up to 75 days old were found near the new nest and were still fed by the parents. Twenty-two of 69 nests (31.9%) had disintegrated by the time the chick fledged, chicks then perched at or near the nest site.

Reproductive effort and timing of breeding

Chatham Island pigeons bred mainly in winter but active nests were found in 10 months of the year. Peak laying in different years ranged from July to September (Fig. 3). The proportion of monitored pairs that attempted to breed varied from 44% in 1993/94 to 100% in 1991/92 and 1994/95. The mean number of breeding attempts pair⁻¹ varied from 0.5 (range 0-2, SD = 0.7, $n = 12$) in 1993/94 to 2.3 (range 1-4, SD = 1.1, $n = 16$) in 1992/93. A summary of reproductive effort is given in Table 1. In the 8 re-nesting attempts for which we know the date of previous failure, pairs began nest building in as little as 4 days (and all within 14 days), after their previous nest failed.

During the 1992/93 and 1994/95 seasons, 75% ($n = 16$) and 50% of pairs ($n = 26$) respectively, re-nested after successfully fledging a chick. In both years at least 1 pair successfully raised 3 consecutive chicks, but the pairs were different on the 2 occasions. During the 1992/93 season, 12 pairs fledged a chick and then re-nested. On 7 (58.3%) of these occasions the pairs built nests, laid, and began incubating before the nestling in their earlier nest had fledged. Similarly, during the 1994/95 season, 3 (37.5%) of 8 re-nestings involved overlapping clutches. Parents began incubating at new nests up to 15 days before their previous chick fledged; both parents fed that nestling when not incubating at the 2nd nest.

Success rate and causes of nest failure

From 1991/92 to 1994/95, 33.8% of 101 located nests failed (Table 1). Because nests were difficult to locate we may have missed those that were lost early in incubation during 1993 and 1994 when many pairs were breeding. Causes of the 32 failures were predation (46.9%), insecure nests (18.7%), no visible embryo development (15.6%), unknown (6.3%), abandoned egg (6.3%), chick death (3.1%) and human disturbance (3.1%). Of 62 1st and 2nd nests, 28% failed as against 32.5% of subsequent attempts ($n = 39$).

During the 1st year of this study we had attempted to control rats at every nest but during the

Table 1 Outcomes of Chatham Island pigeon (*Hemiphaga chathamensis*) nesting attempts on Chatham Island, 1991 to 1995. P, predation; H, handling; I, insecure nest; F, failed to develop; A, abandoned egg; D, dead chick; ?, unknown cause.

Nesting season	Pairs		Nests		% pairs fledging young	Mean no. of young		Cause of failure
	No	% breeding	Found	% failed		Pair ⁻¹	Breeding pair ⁻¹	
1991/1992	11	(91%)	11	36	70	0.64	0.70	P,H,I,?
1992/1993	16	(100%)	37	35	94	1.5	1.5	5P,3F,A, 3I,?
1993/1994	27	(44%)	15	46	53	0.29	0.67	5P,F,I
1994/1995	29	(100%)	45	18	93	1.03	1.03	4P,F,I, A,D

2nd year we employed traps and bait stations at only half of the nests. We observed no significant difference (Fisher's Exact test, $p > 0.1$) in predation rates between protected (58% fledged, $n = 17$) and unprotected nests (66% fledged, $n = 15$).

Predation occurred at egg and chick stages (Table 1). We confirmed harriers (*Circus approximans*) as the predator at 3 nests; 1 with an egg and 2 with chicks. At 1 nest, faeces and finely nibbled eggshell suggested that the predator was a rat (*Rattus spp.*). Coarsely crushed egg remains were thought to indicate predation by a brushtail possum (Brown *et al.* 1996) at another nest. However, at most preyed-on nests we could not determine the predator. The rate of predation was highest (33% of 15 nests) in the poor breeding year of 1993/94, and lowest (4% of 46 nests) in 1994/95.

The presence of 5 eggs on the ground beneath nests was attributed to the insecurity of the nests. Two nests were so sparsely made that the egg fell through or rolled off the material, and in 3 others the surrounding vegetation did not securely support the nests. Such nest collapses may have been caused or accentuated by predator visits or by windy weather.

From 93 breeding attempts for which egg development was ascertained, 5 (5.4%) eggs failed to develop a visible embryo. Three of these failed eggs were recovered in the 1992/93 season; 2 were 2nd clutches from pairs that laid viable eggs in their 1st and 3rd clutches of the season. No pair consistently laid eggs that failed to develop.

Fledgling survival

Of 35 nestlings banded and individually jessed during the first 3 seasons (Table 2), 31 (88.6% of those fledged) were seen when 10–12 months of age. Of the remaining 4, a 7-month-old juvenile was killed by a cat, and the other 3 were not seen again, but may have moved beyond our study area. Several jessed pigeons, both adults and juveniles, have remained undetected by us for periods in excess of a year before being seen again.

Dispersal

In each of the first 2 seasons, 3 nestlings were fitted with radio-transmitters. The movements of these birds after fledging and chance observations of marked juveniles show that 2 females paired on territories within 1 km of their natal areas, and a 3rd female paired on a territory 4 km away from her natal area. The maximum distance recorded was for a male that took up a territory 5.5 km from its natal area. The other 4 males known to have bred moved 0.2, 0.3, 0.6, and 1.5 km. All recorded movements were within 3 km of the coast, but birds which may have moved inland from the study area were less likely to have been located because it was difficult to search there.

Recruitment

Age at first breeding was unknown for most fledglings. Fourteen (40%) of the fledged young paired and bred within the study area. Three females were found breeding at 8, 11, and 21 months of age (mean, 13.3 months), and 5 males bred at 20, 24, 32, 32, and 34 months of age (mean, 28.4 months). A further 5 birds of unknown sex bred at 21, 24, 25, 28, and 29 months of age (mean, 25.4 months).

All 6 fledglings from the 1991/92 season were sighted with mates, and 5 were known to have bred at least once before the end of the study. One female of this cohort successfully fledged 4 young in the 3 seasons following her pairing; the other female fledged a chick in the 1992/93 season, but was not monitored subsequently.

None of the 1992/93 cohort was known to breed in the following season which was a season of poor fruit availability (Powlesland *et al.* 1997) and only 44% of the already established pairs attempted to breed. Of 21 pigeons that fledged in 1992/93, 19 (90%) were sighted subsequently and 9 (43%) were located with nests or dependent fledglings in 1994–95. Of 9 young that fledged during May to September 1992, 7 were found breeding in the study area during the 1994/95 season. In contrast, only 2 of

Table 2 Number of juvenile Chatham Island pigeons (*Hemiphaga chathamensis*) marked as nestlings during the 1991-92, 1992-93 and 1993-94 seasons that were seen again during the 1992-93, 1993-94 and 1994-95 seasons, Chatham Island.

Season	Nestlings marked	Marked juveniles resighted (recruited)		
		1992/1993	1993/1994	1994/1995
1991/1992	6	6(2)	4 (2)	5 (5)
1992/1993	21	-	19 (0)	13 (9)
1993/1994	8	-	-	6 (0)

the 12 young that fledged after the start of October were subsequently found breeding within the study area. None of the young that fledged in 1993/94 was found breeding in 1994/95 despite that being a major breeding season.

DISCUSSION

Nesting biology

The nesting biology of the Chatham Island pigeon, including the roles of the sexes during nest-building and incubation, was similar to the New Zealand pigeon (Moon 1967; Dunn & Morris 1985; Clout *et al.* 1988; James 1995) and other pigeons (Goodwin 1983). Chatham Island pigeon nest-building behaviour was typical of tree-nesting pigeons; the male brought material to the site and the female accepted it and built the structure (Goodwin 1983). Chatham Island pigeons chose nest sites that offered horizontal support for the material and where the nest was well screened from above and the sides by vegetation. Presumably good cover was important to reduce the likelihood of the adult or nestling being seen by avian predators such as the Australasian harriers, which prey on nestlings of a variety of species, including Chatham Island and New Zealand pigeons (Dunn & Morris 1985). Before European settlement, the New Zealand falcon (*Falco novaeseelandiae*) is likely to have been a key predator of the Chatham Island pigeon (R. Holdaway pers. comm.).

The Chatham Island pigeon commonly nests low to the ground. This is rare for New Zealand pigeons but has been reported on the Hen and Chickens Islands (Moon 1967; Pierce & Graham 1995) where the Pacific rat was the only predatory mammal. The contents of pigeon nests built on, or within 1 m of the ground, were readily accessible even by less arboreal introduced predators such as Norway rats and weka. Such nests may also be put at risk by stock movements in areas that are not adequately fenced. Higher nests can be reached easily by possums, cats, and ship rats, which readily climb to the canopy.

Chatham Island pigeons lay a single white egg.

The egg weight relative to mean body weight is similar for the 2 New Zealand pigeons (4.0% for CIP and 4.3% for NZP; Robertson 1988). The incubation pattern of males and females closely resembled that of the New Zealand pigeon (Moon 1967; James 1995). Time off the nest allowed each gender roughly equal daylight hours for provisioning. Although other observers have noted that New Zealand pigeons add twigs to the nest at changeovers during the incubation and early in the nestling-rearing phases (Moon 1967; Dunn & Morris 1985), the frequency of such additions has not been quantified. Twigs were carried on 69.4% of occasions that a Chatham Island pigeon came to the nest to relieve its partner. As the twig was not presented to the mate as part of a pair-bonding or greeting ceremony, but was added to the nest, possibly the activity helped to maintain the nest structure.

The incubation period for the Chatham Island pigeon was 27-29 days, close to or within the ranges reported for New Zealand pigeons; 29-30 days (Moon 1967), 29-30 days (Dunn & Morris 1985), 28-29 days (Clout 1990), and 25-30 days (James 1995). Infrequent feeding of nestling Chatham Island pigeons by day, especially when less than 2 weeks old, has also been noted for New Zealand pigeon nestlings (Moon 1967), but probably under-represents total feeding. Using a video camera and recorder with infra-red lighting, James (1995) showed that nestling New Zealand pigeons less than a fortnight old were fed mainly between midnight and sunrise. Perhaps chicks are fed infrequently by day to reduce the frequency of visits to the nest and therefore the likelihood of the nest being found by avian predators such as harriers. Certainly chicks' crops can accommodate a considerable quantity of rich food in the form of crop milk and partly digested food fed by their parents. The large volume given probably sustains the chick when left for long periods of the day after it is 2 weeks old.

Length of nesting cycle

Both surviving species have low productivity given that the clutch size is 1, and the nest cycle from nest building to the chick fledgling lasts about 3 months.

Even after fledging, young Chatham Island pigeons continue to depend on their parents for food for at least a further 3 weeks. Clutch-overlap is a means by which a species can increase its reproductive output when it cannot increase clutch size, or has a brief energetically limiting phase in the nesting cycle. Both species have a herbivorous, low-protein diet so production of crop milk for the young chick may be energetically limiting (Clout *et al.* 1988). Clutch-overlap has been recorded for several of the Columbidae (Robertson 1985), including the New Zealand pigeon (Clout *et al.* 1988). Chatham Island birds were able to sustain overlapping clutches only in those breeding seasons when nutritious food was particularly abundant (Powlesland *et al.* 1997). Clutch-overlap decreased the time taken for a pair of pigeons to complete 2 nesting cycles from about 240 days (nest-building, 3 days; pre-laying period, 5; incubation, 28; nestling, 45; fledgling, 40) to about 185 days, a 23% reduction. Clutches were overlapped in half of the 20 occasions that pairs fledged a chick and re-nested.

When pairs overlapped clutches, they fed their first fledglings for only about 20 days compared with about 40 days when raising only 1 brood. Chatham Island pigeons overlapped clutches only in years of abundant food. It is possible that the shorter provisioning period in those years resulted in lighter chicks, but given the abundant food this may have been of no consequence to chick survival. Our data were insufficient to detect any difference in the survival of these fledglings. The Mauritius pink pigeon (*Columba mayeri*) rarely raised more than 1 chick and never overlapped clutches, but fledglings whose parents had access to food supplements reached independence at 10-20 days, whereas young of pairs without access to supplementary food took 60-90 days (Jones *et al.* 1992).

Food determines nesting season

Quality and quantity of food were the main factors controlling nesting in the Chatham Island pigeon (Powlesland *et al.* 1997). During the winters of 1992 and 1994, when fruits were abundant, most pigeons began their nesting in winter (Fig. 3) when other environmental factors would have been at their least favourable (i.e. shortest day-length and coldest temperatures). Although New Zealand pigeons have been recorded nesting in winter (Genet & Guest 1976; Pierce & Graham 1995), most nests have been found during spring and summer (Dunn & Morris 1985; Clout *et al.* 1988). James (1995) concluded from his study at Wenderholm, Auckland, that the ultimate factors controlling the breeding of pigeons there were most likely food availability and temperature. Results from other studies indicate that food has a pronounced impact on the timing and duration of pigeon and dove nesting. For example Mauritius pink

pigeons that fed on food supplements nested 3 months earlier than those that did not (Jones *et al.* 1992). Captive New Zealand pigeons at the National Wildlife Centre, Wairarapa, with *ad libitum* access to nutrient-rich foods frequently raised 2 or 3 chicks year⁻¹ (M. Bell, pers. comm.). The ability of Chatham Island pigeons to nest earlier and for longer in years with abundant food (Powlesland *et al.* 1997) was important in enabling them to increase their numbers quickly after feral cat, rat and possum population densities were reduced (Grant *et al.* 1997). As well as preying on nests, rats and possums overlap considerably with pigeons in their use of plant species (Tisdall 1992). Their feeding on fruit competes directly with the birds and their damage to bark and foliage of some species (notably hoho) undoubtedly has an impact on fruiting ability. Though not quantified, it seems likely that the amount of fruit available to Chatham Island pigeons may have increased as the pest populations declined.

Nesting effort and success

The nesting effort of Chatham Island pigeons varied from year to year. Only 44% of pairs nested in 1993/94, but all pairs nested in 1992/93 and 1994/95 when many of them attempted to rear two successive fledglings (Powlesland *et al.* 1997). Similarly, the nesting effort of New Zealand pigeons has been found to vary between years. At Pelorus Bridge, Marlborough, nesting began in summer and eggs were laid as late as June (winter) in good fruiting years (Clout *et al.* 1995a). At the same site no pairs nested in a very poor fruiting season.

Prolific breeding by Chatham Island pigeons, in conjunction with sustained control of feral cats and brushtail possums, resulted in a marked increase in the numbers of pigeons during the study (Grant *et al.* 1997). Pairs re-nested promptly after the failure of a nesting attempt and were found nest-building within a week of a failure. Similarly, New Zealand pigeons will lay again within 8 days of losing an egg (Clout *et al.* 1995a). The most nestings we recorded for a pair of Chatham Island pigeons in a season was 4, 2 of which were successful.

As well as re-nesting promptly, Chatham Island pigeons reared 2 fledglings in some seasons, and exceptionally 3. We suggest that this may be attributed to the populations of frugivores and herbivores (including pigeons) being well below the levels the habitat could sustain after the possum population declined. No comparative information on the reproductive output of pigeons on the mainland is available because a high proportion of their nesting attempts are foiled by predators (Clout *et al.* 1995a; Pierce & Graham 1995).

The overall nesting success of *parea* during this study was 68% ($n = 101$). A very similar result (63%, $n = 16$) was observed for New Zealand pigeons on

predator-free Lady Alice and Coppermine Islands, Northland, where Pacific rats were present but not thought to be a threat to pigeons (Pierce & Graham, 1995). In contrast, the nesting success of pigeons at 4 mainland sites (without any predator or competitor control) was 22.2 % ($n = 45$) at Pelorus Bridge during 1984-91 (Clout *et al.* 1995a), 0% ($n = 9$) at Mohi Bush during 1988-91 (Clout *et al.* 1995a), 0% ($n = 27$) at Wenderholm during 1988-92 (Clout *et al.* 1995b), and 19% ($n = 31$) at Maungatapere, Northland, during 1991-93 (Pierce & Graham 1995). At Wenderholm during the 1992/93 nesting season rats were poisoned and Clout *et al.* (1995b) reported that pigeon nesting success increased from 0% to 45.5% ($n = 11$). These results indicate that predators have a major impact on the productivity of New Zealand pigeons and that predator control can lead to rapid recovery of pigeon populations.

Population recovery

Working with rare species can present researchers with considerable problems in interpretation. In this study, the lack of previous information (on either Chatham Island pigeons or their food-plant seasonality), the lack of a non-managed, control population and small sample sizes limited our ability to draw strong conclusions. With the population of pigeons down to <50 birds at the start of our study we encouraged the management decision to augment control of mammalian pests at the site, based on our knowledge of the impact of mammalian predators on other New Zealand forest bird species. The hoped-for dramatic population increase happened during our study yet the study presents only circumstantial evidence that removal of predators caused the increase.

Once possum and feral cat numbers had been reduced to low levels (Grant *et al.* 1997) several factors enabled the pigeon population to increase. Nesting success was 68% as against 0-22% for pigeons on the mainland (Clout *et al.* 1995a; Pierce & Graham 1995). Chatham Island pigeons were able to reduce the length of the nesting cycle by nearly 25% by overlapping their clutches. If a nest failed part way through the nesting season, pairs quickly laid a replacement clutch. Thus, in 2 of the 4 nesting seasons when fruit (particularly hoho) was abundant, all pairs were able to breed and some reared 2 or 3 broods within a season. Survival to 1 year of age, and recruitment were both high. Nearly 90% of 35 marked nestlings were seen when 10-12 months of age. By this age, 2 of the 3 females had bred, while did not breed before 2-3 years of age. The sexual difference in mean age at first breeding possibly results from males having to acquire and defend a territory for nesting, whereas young females were able to pair with mature, unpaired males that already held a territory. Adult annual survival rate was 0.96 (Grant *et*

al. 1997). The combination of all these factors allowed the number of adult pigeons in the Awatotara and Tuku study areas to increase 3-fold from 1990 to 1994 (Grant *et al.* 1997).

The observed dispersal of juveniles to sites 4-6 km from their natal ranges suggests that sustained pest control will allow the pigeon population to increase and re-colonise distant areas of suitable habitat. Foraging and nesting habitats of the pigeons have been greatly modified in the past by human disturbance. Chatham Island pigeons regularly nest near the ground in relatively young vegetation, so fencing and removal of feral stock, particularly from land with some forest remnants, can rapidly increase the number of suitable breeding sites.

Pigeons are the only large frugivorous birds on the Chatham Islands, and so they play a crucial role in the dispersal of a wide variety of forest seeds. We are optimistic that, given the species' longevity, periodic but intensive control of pest mammals, coupled with further habitat protection, will ensure the conservation of healthy pigeon populations that can perform this vital function.

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Status and breeding biology of the Chatham Island tomtit (*Petroica macrocephala chathamensis*)

R.G. POWLESLAND

Science & Research Unit, Department of Conservation, P.O. Box 10-420, Wellington, New Zealand
rpowlesland@doc.govt.nz

D.V. MERTON

Biodiversity Recovery Unit, Department of Conservation, P.O. Box 10-420, Wellington, New Zealand

D. CROUCHLEY

Te Anau Field Centre, Department of Conservation, P.O. Box 29, Te Anau, New Zealand

S. O'CONNOR

Biodiversity Recovery Unit, Department of Conservation, P.O. Box 10-420, Wellington, New Zealand

Abstract The population status of the Chatham Island tomtit (*Petroica macrocephala chathamensis*) was determined for each island of the Chathams group, east of New Zealand. Also, the breeding biology of the population on Rangatira (South East Island), which is free of introduced mammalian pests, was determined from observations made during 8 breeding seasons, 1981/82 to 1988/89. The total population of the Chatham Island tomtit is estimated to be < 1000 birds: Chatham, extinct; Pitt, c. 500; Rangatira, 200-300; Mangere, 70-100; Tapuaenuku (Little Mangere Island), occasional vagrant. Regeneration of scrub and forest habitats on 3 islands is likely to lead to gradual increases in the tomtit populations there. The nesting season on Rangatira was from late September to late January, which was just sufficient time for a pair to rear 2 broods successfully. Of 378 nests, 43% were in tangles of pohuehue (*Muehlenbeckia australis*) vines, 16% in cavities, 12% on a branch, trunk, or stump covered in vines, and for 21% the site was not indicated. The mean height of nests was 2.7 m, and the mean duration of the pre-laying period was 5.9 days. Mean clutch size was 3.1 eggs, and incubation usually started on the day the last egg was laid (82%). Only females were seen incubating, with males feeding their mates at regular intervals. Of 97 eggs, 83% hatched, and 93% of 15 nesting attempts resulted in at least 1 fledgling each. The high nesting success, in comparison to that of mainland populations, is attributed to the absence of mammalian predators on Rangatira. Although our study provided much information for the early stages of the nesting cycle, few data are available for other aspects of the Chatham Island tomtit's breeding biology, such as length of incubation, and nestling and fledgling periods.

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Keywords *Petroica macrocephala chathamensis*; Petroicidae; Rangatira Island; distribution; status; breeding biology

INTRODUCTION

Before European settlement of the Chathams group of islands in 1840-50, the black robin (*Petroica traversi*) and Chatham Island tomtit (*Petroica macrocephala chathamensis*) coexisted on Mangere Island (Fleming 1939). However by c. 1900, the black robin survived only on Tapuaenuku (Little Mangere Island). Following translocations and the successful intensive management programme during the 1980s (Merton 1990; Butler & Merton 1992), the black robin is present again on Mangere and on

Rangatira (South East Island). What impact the robin populations on these 2 islands will have on the tomtit populations is unknown. With regard to foraging behaviour of the 2 species on Rangatira, McLean *et al.* (1994) concluded that there was little evidence for niche separation. If so, once all suitable habitat is occupied the 2 species are likely to compete for resources more frequently. In the long term, such competition could result in niche separation, and perhaps even habitat separation, if both populations persisted. Although black robins and Chatham Island tomtits do not have mutually exclusive territories, robins have been seen to dominate tomtits at feeding sites, and to persistently

chase nesting tomtits when the 2 species nested close to each other (Butler & Merton 1992), but the opposite has been seen too (Flack 1977; DVM pers. obs.).

Rangatira is particularly important in the long-term conservation of the Chatham Island tomtit because of its size (218 ha), much of which is covered by forest and scrub suitable for tomtits, and its being free of introduced predators and browsers. However, its importance may be compromised by the increasing robin population there. Therefore we need to know the status of the tomtit population on each island in the Chathams group, and to summarise what is known about the tomtit's breeding biology, should it be necessary to establish new populations of tomtits.

The New Zealand tomtit (*Petroica macrocephala*) is particularly suitable for detailed studies of breeding biology because it can be trained to approach people for a food reward so as to assess a pair's breeding status, and nests can be found and closely monitored with little chance of desertion (Knegtmans & Powlesland 1999). As a result, the breeding biology of 3 subspecies of *Petroica macrocephala* - North Island tomtit (*P. m. toitoi*) (Brown 1997; Knegtmans & Powlesland 1999); South Island tomtit (*P. m. macrocephala*) (Kearton 1979); Snares Island tomtit (*P. m. dannefaerdi*) (Best 1975; McLean & Miskelly 1988; Miskelly 1990) - have been studied. However, the breeding biologies of the Auckland Island tomtit (*P. m. marrineri*) and Chatham Island tomtit (*P. m. chathamensis*) have not been studied in detail, although McLean & Miskelly (1988) included some information on each of these subspecies.

For *P. m. chathamensis* during the 8 breeding seasons 1981/82 to 1988/89, at least 378 nests were found on Rangatira, when an intensive effort was made to boost black robin numbers by cross-fostering eggs and young of this species to the congeneric Chatham Island tomtit (Merton 1990; Butler & Merton 1992). As a result of closely monitoring and recording the activities at many tomtit nests, particularly until tomtit eggs or chicks were replaced with those of black robins, detailed information on the early stages of the breeding cycle of the Chatham Island tomtit became available. In this paper we present the history and status of tomtit populations on each island of the Chathams group. In addition, information on the breeding biology of the tomtit on Rangatira is summarised from 8 seasons of monitoring.

STUDY AREA

Rangatira (44° 20' S, 176° 10' W; 3 km SE of Pitt Island) is the most important reserve for birdlife in the Chathams group (Fig. 1). At 218 ha, it is one of the largest islands free of introduced mammals in

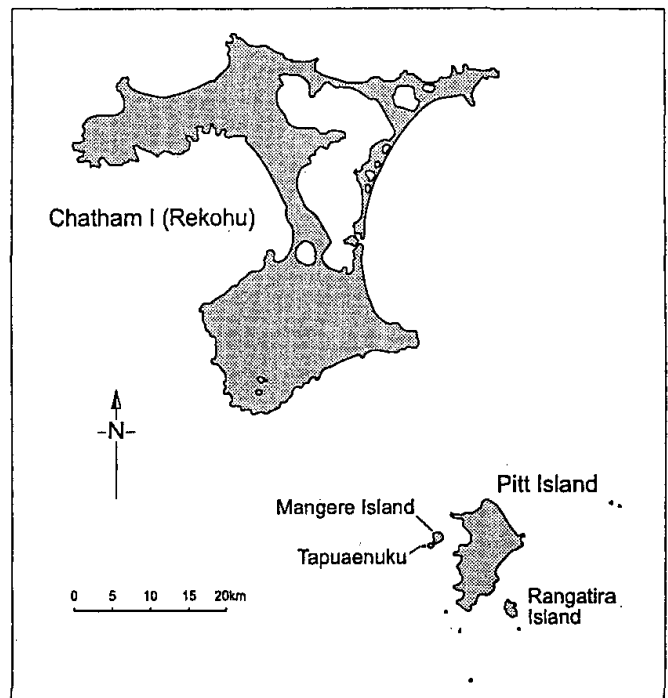


Fig. 1 Chatham Islands group showing the location of each island mentioned in the text.

the New Zealand region. Its geography, geology, vegetation, and bird life, and the impact of farming on it are described by Ritchie (1970), Butler & Merton (1992), West (1994), and West & Nilsson (1994). Farming began in 1840 and ended in 1961, by which time only about a third of the island remained forested, much of the rest being in pasture. The main canopy species are Chatham Island akeake (*Olearia traversii*), mahoe (*Melicytus chathamicus*), matipo (*Myrsine chathamica*), and ribbonwood (*Plagianthus chathamicus*). Once grazing ceased, the forest remnants regenerated quickly and the grasslands were replaced by bracken (*Pteridium esculentum*), water fern (*Histiopteris incisa*), and pohuehue (*Muehlenbeckia australis*) vines (Butler & Merton 1992; Nilsson *et al.* 1994). By 1993, 45% of the island was covered by forest, 15.5% by grasslands, 11% by associations of pohuehue vines, bracken and akeake trees, 15% by scrub and herbfield, and 13.5% by rock, low cliffs, and wave platforms (Nilsson *et al.* 1994).

METHODS

The main technique for promoting the conservation of the black robin during the 1980s involved fostering eggs and chicks to Chatham Island tomtit nests, and then transferring the robin chicks back to robin nests just before fledging (Merton 1990; Butler & Merton 1992). To cross-foster, tomtit pairs were fed commercially available mealworm (*Tenebrio molitor*) and waxmoth (*Galleria mellonella*) larvae or invertebrates caught locally on Rangatira, so that their breeding status could be quickly determined and any

nests found. If the female was attracted, the nest could be found by following her back to it. If the male was attracted, he would usually go to the vicinity of the nest with food and feed his mate, and she could then be followed to the nest. Some nests were destroyed by observers during building or incubation if they were too exposed to weather or the numerous seabirds crashing through the canopy, were difficult to access for fostering activities, or the nesting stage was not in synchrony with that of robins (Butler & Merton 1992). Pairs were therefore compelled to re-nest at more convenient times, or in more convenient locations for cross-fostering. The destruction of some nests of the Chatham Island tomtit, a totally protected species, was considered justified in an attempt to save the black robin given that there were just 7 black robins at the start of the 1981/82 nesting season compared to several hundred Chatham Island tomtits. As a result, most of the 99 Chatham Island tomtit eggs in New Zealand museums that were measured for this study originated from Rangatira Island during 1981-87, and were collected because they were abandoned during cross-fostering procedures, or nests were removed during incubation to compel the birds to re-nest.

Once a tomtit nest suitable for cross-fostering was found, its location was marked with coloured plastic tape, and its contents were checked daily during the pre-laying and egg-laying stages. During laying some nests were moved into a nest box. The roof was progressively lowered and a grille added over the entrance once incubation had started to protect fostered robin eggs and chicks from extremes of weather, seabirds crashing on to the nest, and interference by introduced starlings (*Sturnus vulgaris*) (Merton 1990; Butler & Merton 1992). If a nest was found during incubation, similar protection was afforded, and eggs were candled to determine the approximate day of incubation. Eventually, many tomtit eggs or chicks were replaced with robin eggs or chicks for cross-fostering. As a result, the sample sizes of data relating to later stages of the tomtit nesting cycle (hatching success, nestling success) are small. Only in the first season (1981/82), when protection and fostering techniques were being developed, were some tomtit nesting attempts monitored to completion without the clutch or brood being altered in anyway. Tomtit nests were not closely monitored if they were not required for the cross-fostering programme. Records of observations obtained during the nesting cycle of a specific pair (identified by location of their territory) and the contents of their nest were entered on to a record sheet. None of the tomtits were banded for individual identification.

If it was not observed directly, the first-egg laying date of each clutch was estimated from the degree of embryo development, or the age of nestlings (allowing 17 days for incubation). It was as-

sumed that incubation began on the day the last egg was laid, and that the eggs were laid at daily intervals.

The computer package SigmaStat[®] was used for Student's *t*-tests, Mann-Whitney Rank Sum tests, and Kruskal-Wallis 1-way analysis of variance to compare various data sets. Where either the *t*-test or Kruskal-Wallis 1-way analysis of variance was inappropriate because the data were not normally distributed, the Mann-Whitney Rank Sum test and Kruskal-Wallis 1-way analysis of variance on ranks, respectively, were used to test for significance.

RESULTS

Distribution and status

The Chatham Island tomtit once inhabited scrublands and forests of Chatham, Pitt, Rangatira, Mangere, and Tapuaenuku Islands of the Chathams group (Fleming 1939; Oliver 1955). Even by 1938, the distribution of the tomtit had apparently shrunk because Fleming (1939) found it only in southern Chatham Island, where it was not plentiful. Today the species is probably extinct on Chatham Island, the last records being of a bird near Green Point in 1975 (Freeman 1994), and 1 in the Tuku Valley in 1976 (L. Howell pers. comm.). Although 40 tomtits were transferred from Rangatira to the Tuku Valley of Chatham Island in February 1998, none have been seen there since.

In 1968, Merton & Bell (unpubl. data) failed to locate tomtits on Tapuaenuku (17 ha), but found small numbers on Mangere (113 ha). Tomtits were removed from Mangere (19 birds) and Tapuaenuku (5) in 1976 so that they would not compete with the then critically endangered black robin (Butler & Merton 1992). There was no indication that there had been a self-sustaining population of tomtits on Tapuaenuku before 1976; the few recorded during earlier visits were considered to have dispersed there as juveniles from Mangere or Pitt Islands (Butler & Merton 1992). Vagrants from Pitt Island were occasionally seen on Mangere in the 1980s. During 1987 (8 birds), 1988 (9), and 1989 (21), tomtits were reintroduced to Mangere from Rangatira (Butler & Merton 1992), and there has been a sparse but widespread breeding population there since 1990, with an estimated 70-100 birds by 1999 (DVM & SO pers. obs.). No pairs had re-established on Tapuaenuku by 1998, just a lone female being seen there on 28 January 1998 (M. Bell, pers. comm.).

Lindsay *et al.* (1959) saw tomtits frequently in the southern portion of Pitt Island (6203 ha) during a visit in 1957, but in 1968, Merton & Bell (1975) recorded tomtits as scarce on the island. There are 3 reserved forest blocks on Pitt Island, the northern reserve (Ellen Elizabeth Preece Conservation Covenant; 53 ha), the central reserve (Pitt Island Scenic

Reserve - Waipaua block; 692 ha, plus the adjoining Fredrick & Mary Hunt Memorial Conservation Covenant; 135 ha), and the southern reserve (Pitt Island Scenic Reserve - Glory and Canister Cove block; 615 ha). The northern reserve is fenced to exclude pigs, sheep, and cattle, and the vegetation is regenerating well (Walls 1999; Walls *et al.* 2000). Some cat control has been carried out there since 1996 (S. King, pers. comm.). The southern reserve is fenced but contains feral pigs, and regeneration is limited. The central reserve contains many feral sheep and pigs, and the forest has little understorey and is deteriorating (Walls 1999; Walls *et al.* 2000). Five-minute counts of forest birds (Dawson & Bull 1975) in January-February 1996, 1998, and 1999 indicated that tomtits were present in each of the reserves, being most abundant in the northern reserve (southern, 0.48 tomtits count⁻¹; central, 0.84; northern, 1.43; S. King, pers. comm.). Given the size of the reserves and the widespread presence of tomtits in them, we estimate that there are about 500 tomtits on Pitt Island.

The Chatham Island tomtit has been recorded as abundant on Rangatira (*c.* 122 ha of tomtit habitat in 1993; Nilsson *et al.* 1994) since 1937 (Fleming 1939; Dawson 1955; West 1988; Freeman 1994), and the population has been regarded as being the largest in the Chathams group (Nilsson *et al.* 1994). However, given the extent and quality of forest and scrub habitats on Pitt Island compared to that on Rangatira in 1961, when farming ceased on the latter (Nilsson *et al.* 1994), it seems likely that tomtit numbers were then greater on Pitt. By comparing numbers of tomtits with those of black robins on Rangatira in 1999, when all the latter species could be counted because all individuals were colour-banded, probably 200-300 tomtits were present (DVM & SO, pers. obs.).

Breeding season

On Rangatira, the first tomtit clutches each season were laid during late September and the first half of October, and the last clutches during late November-early December (Table 1). As incubation and nestling rearing lasted about 17 and 19 days, respectively, and fledglings were fed for 3-4 weeks before becoming independent (see below), a few late nesting attempts would not have been completed until late January. Thus, the tomtit nesting season on Rangatira lasted 4.5 months at most.

Nest building

Nests were built solely by the female, with the male bringing her food regularly. The nests varied little in composition, except for the types of coarse materials (such as a few twigs or pieces of bark bound with cobwebs) used to form the base. While the bulk of each nest consisted of mosses and the lace-like dried inner bark from dead ribbonwood trees, other ma-

Table 1 Dates of first and last Chatham Island tomtit (*Petroica macrocephala chathamensis*) clutches laid each breeding season on Rangatira, 1981-89. Dates are observed or estimated laying dates for the 1st egg of each clutch.

Season	Laying date	
	First clutch	Last clutch
1981/82	10 Oct	30 Nov
1982/83	18 Oct	24 Nov
1983/84	3 Oct	5 Dec
1984/85	29 Sep	20 Nov
1985/86	11 Oct	14 Dec
1986/87	7 Oct	8 Dec
1987/88	14 Oct	10 Dec
1988/89	27 Sep	8 Dec

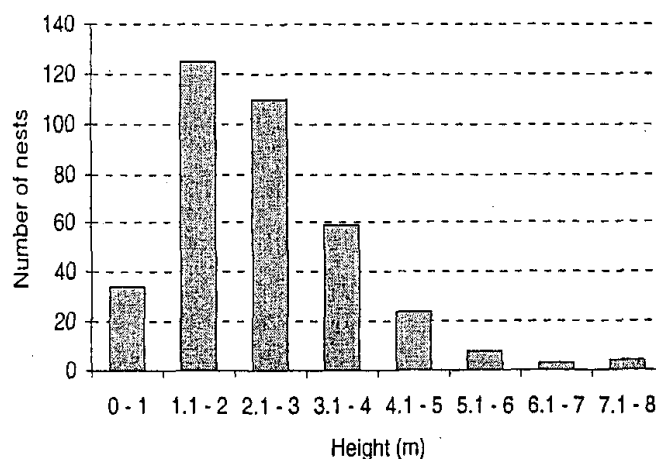


Fig. 2 Number of Chatham Island tomtit (*Petroica macrocephala chathamensis*) nests ($n = 370$) found on Rangatira Island during 1981-89 in various height categories.

terials included leaves, lichens, twigs and spider web. The nest lining was mosses and/or feathers, predominantly of seabirds and Chatham Island red-crowned parakeets (*Cyanoramphus novaezelandiae chathamensis*). On average, nests took 3.4 days to build ($n = 23$, range = 2-8, SD = 1.31).

Nest site

Table 2 shows the types of nest sites chosen by Chatham Island tomtits during each of 8 breeding seasons, 1981-89. In total, 43.4% of nests ($n = 378$) were in tangles of pohuehue vines, 16.2% were in hollow branches or cavities on trunks, 11.7% were on a branch, trunk or stump covered by vines, 6.3% were on stumps, 0.5% were on branches, 0.5% were in shrubs, 0.5% were in nest boxes, and for 20.9% the site was not indicated.

The mean height of 370 nests during 1981-89 was 2.7 m (SD = 1.52). Although the lowest nests were at 0.5 m and the highest at 8.0 m, 88.6% were < 4.1 m above ground (Fig. 2). Mean nest height varied

Table 2 Frequency of use by Chatham Island tomtits (*Petroica macrocephala chathamensis*) of 7 types of nest sites, plus unknown sites, on Rangatira, 1981-89. Vines, pohuehue (*Muehlenbeckia australis*); cavities, in hollow branches and trunks.

	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89	Total	Percentage
In tangle of vines	12	14	23	23	6	23	25	38	164	43.4
In cavity	5	5	10	11	6	6	8	10	61	16.2
On solid surface under vines	3	1	17	7	5	5	5	1	44	11.7
On stump	-	3	5	5	1	6	2	2	24	6.3
On branch	1	-	-	-	-	1	-	-	2	0.5
In shrub	-	-	-	1	-	-	1	-	2	0.5
In nest box	-	-	-	1	-	1	-	-	2	0.5
Unknown	-	10	2	10	3	12	24	18	79	20.9
Total	21	33	57	58	21	54	65	69	378	

Table 3 Mean height above ground (m) of Chatham Island tomtit (*Petroica macrocephala chathamensis*) nests on Rangatira for each of 8 seasons, 1981-89.

Season	Mean height	Range	SD	n
1981/82	2.74	1.0-7.5	1.44	21
1982/83	3.22	1.0-6.0	2.09	33
1983/84	2.29	0.5-6.0	1.13	57
1984/85	2.48	0.5-7.5	1.29	58
1985/86	3.32	1.5-7.0	1.50	21
1986/87	2.42	0.5-7.0	1.31	52
1987/88	3.09	1.0-6.0	1.47	65
1988/89	2.92	0.5-8.0	1.75	63

between breeding seasons (Table 3), the difference being significant (Kruskal-Wallis 1-way analysis of variance on ranks, $H = 21.3$, $df = 7$, $P = 0.003$).

Pre-laying

Males fed their mates regularly during the pre-laying period, from completion of nest building until laying of the first egg, which lasted, on average, 5.9 days ($n = 88$, range = 2-15, $SD = 2.81$). Its mean duration was longer in October (mean = 7.1 days, range = 2-15, $SD = 3.13$, $n = 45$) than in November (mean = 4.6, range = 1-11, $SD = 1.72$, $n = 43$; Mann-Whitney Rank Sum test, $P = 0.0048$).

Eggs

Seventy-eight Chatham Island tomtit eggs, all collected during 1981-87 from Rangatira, were examined at the Museum of New Zealand. They ranged in shape from typically ovoid to a few that were almost spherical. They were mainly white with brown and grey spots and blotches concentrated at the larger end, but on 3 the markings were concentrated at the narrower end, and 5 had fine brown-grey spots distributed evenly over the entire shell.

The mean length and maximum breadth of 99 Chatham Island tomtit eggs, all from Rangatira (78, Museum of New Zealand; 10, Auckland Institute and Museum collected in October-November 1983; 11 measured by DC during the 1981/82 season), were 19.1 mm ($SD = 0.62$; range = 17.4 - 20.3) and 15.0 mm ($SD = 0.31$; range = 14.2 - 15.6) respectively. Most (95.7%, $n = 221$) eggs were laid at daily intervals; the rest were laid during the 2nd day.

Using the formula of Hoyt (1979) for estimating egg mass from shell measurements in cm (egg mass = $km + \text{length} + \text{breadth}^2$, where $km = 0.548$), the mean fresh weight of a Chatham Island tomtit egg was estimated to be 2.35 g. Mean adult female weight was 12.7 g ($n = 28$, $SD = 0.67$; M. Bell, pers. comm.), so the modal clutch size of 3 eggs represented 55.5% of female weight.

Table 4 Clutch sizes of Chatham Island tomtits (*Petroica macrocephala chathamensis*) at fortnightly intervals through the breeding season on Rangatira, 1981-89.

	Clutch size			Mean
	2-egg	3-egg	4-egg	
Late Sep		2		3.00
Early Oct	3	25	5	3.06
Late Oct	9	89	21	3.10
Early Nov	4	54	18	3.18
Late Nov	3	31	10	3.16
Early Dec	1	5	3	3.22
Late Dec		1		3.00
Total	20	207	57	3.13

Clutch size

Clutch size was 2 – 4 eggs, with most of the 284 clutches from the 8 breeding seasons being 3 eggs (7.0% 2-egg clutches, 72.9% 3-egg clutches, 20.1% 4-egg clutches). Clutch size did not vary significantly between breeding seasons (Kruskal-Wallis 1-way analysis of variance on ranks, $H = 13.1$, $df = 7$, $P = 0.069$). Mean clutch size over all seasons was 3.13 eggs ($n = 284$, $SD = 0.51$). Mean clutch size appeared to vary through the breeding season (Table 4), but the differences were not significant (Kruskal-Wallis 1-way analysis of variance on ranks, $H = 3.12$, $df = 6$, $P = 0.793$).

Incubation

Incubation started mainly on the day the last egg was laid (82.4%, $n = 85$) (Table 5). However, occasionally incubation started on the day the penultimate egg was laid (9.4%), or the day after the clutch had been completed (8.2%).

Only females were seen to incubate ($n = 295$ observations). Their mates took food to them regularly throughout the day, but the frequency of food presentation was not quantified. The male gave short bursts of full song as he approached the nest. On leaving the nest and arriving beside her mate, the female gave a begging display in which she fluttered partly open wings while crouching low on the perch. After the male fed her she usually spent a little time preening and/or foraging before returning to the nest.

In the 1 nest followed to hatching, incubation lasted 17 days from the laying of the last egg until the chicks hatched. One female monitored incubated a clutch of plastic eggs for 33 days, deserting on the 33rd or early on the 34th day.

Nestlings

Of 97 eggs in 34 clutches during 1981-89, 81 (83.5%) hatched. All 3 eggs of 1 of the 34 clutches were infertile, but why the other 13 failed to hatch is unknown.

Table 5 Day on which incubation was determined to have started with regard to the laying of each egg of various clutch sizes for Chatham Island tomtits (*Petroica macrocephala chathamensis*) on Rangatira, 1981-89.

	Clutch size		
	2-egg	3-egg	4-egg
Day egg 1 laid	1	-	-
Day egg 2 laid	3	2	-
Day egg 3 laid		59	5
Day egg 4 laid			8
Day after last egg laid		6	1

Nestlings were almost naked until day 3, but by day 5 were covered with down. Their eyes began to open about day 7, and the wing and tail feathers were fully formed by day 10, when head and body feathers were developing. By day 15 the nestlings were almost fully feathered and could be readily sexed by the difference in plumage colour (Heather & Robertson 1996). Both parents fed the nestlings, but only the female brooded them. Sometimes the brooding female gave a begging display and chick-like calls when the male approached with food, then left the nest to allow the male to feed the nestlings.

For 6 broods in 1981/82, the mean length of the nestling period was 18.8 days (range = 17-21). Also in 1981/82, all 23 chicks in 11 nests fledged, and 93.3% of 15 nesting attempts resulted in at least 1 fledgling each. One brood which fledged on 18 November 1981 was still being fed by their parents 25 days later, although they were catching much of their own prey by then.

Re-nesting interval

The mean time taken for a female to re-nest, having deserted her nest or having had it destroyed, was 1.75 days ($n = 36$, range = 1-5, $SD = 1.00$). Although the sample sizes were small, the data suggested that egg-laying and chick-rearing females were slower to start re-nesting than those at other stages of the nesting cycle (Table 6).

DISCUSSION

Status

In 1998/99, Chatham Island tomtits were found on Mangere (70-100), Rangatira (200-300), and Pitt (*c.* 500) Islands, with a total population of 770-900 birds. Given the continuing regeneration of shrub and forest habitats on Mangere and Rangatira Islands, and to a limited extent on Pitt Island, it is likely that the tomtit populations on these islands will gradually increase. Even if tomtits are able to re-colonise Tapuaenuku, a population there, given the small size of the island, would have little impact on the total number of Chatham Island tomtits.

Table 6 Time taken by female Chatham Island tomtits (*Petroica macrocephala chathamensis*) to start nest building after deserting a nest or having had their nest destroyed, Rangatira, 1981-89.

Stage of cycle	Number of days					Mean
	1	2	3	4	5	
Nest building	6	-	-	-	-	1.0
Pre-lay	-	1	-	-	-	2.0
Laying	1	1	1	1	1	3.0
Incubation	12	6	3	-	-	1.6
Chick rearing	-	2	1	-	-	2.3
Total	19	10	5	1	1	1.7

What would have a major influence on total numbers, and therefore the long-term survival of the subspecies, would be more extensive management of pest species (browsers and predators) in the reserves on Pitt Island to promote habitat regeneration and reduce predation, and the re-establishment of tomtits on Chatham Island. Because the birds were not monitored during the first few days after release, it is not known why the transfer of tomtits to Chatham Island in 1998 failed. The most likely reasons are that there was high mortality immediately after release as a result of the transfer process, or predation at the release site; or the birds dispersed too far. It is unlikely that there was high mortality immediately after release because all the birds survived the transfer, and enough Chatham Island tomtits transferred to Mangere in 1987-89 survived to breed and establish a population there. Unless the roosting behaviour of Chatham Island tomtits differs significantly from that of mainland tomtits because of their naivety to mammalian predators, it is unlikely that adults would be particularly vulnerable to predation by rats (*Rattus* spp.), the most likely new predator they would encounter on Chatham Island. Perhaps most likely is that those that survived the transfer dispersed widely within the Tuku Nature Reserve and adjacent covenants (1214 ha), so that Department of Conservation staff and volunteers had little chance of seeing them while engaged in other conservation activities in the reserves.

Tomtit populations on mainland New Zealand survive in forests inhabited by the same species of predators that occur on Chatham Island, plus mustelids (*Mustela* spp.). It therefore seems reasonable to make another attempt to re-establish tomtits on Chatham Island. However, we suggest that the birds are released in spring, rather than in autumn, as in 1998, into a relatively small, stock-proof, native forest reserve (such as 19 ha Nikau Bush Scenic Reserve) where rat and cat numbers are maintained at very low densities, and that the birds are

monitored closely for several months to determine survival and nesting success. Given that such actions have resulted in the establishment of New Zealand robin (*Petroica australis*) populations at several mainland sites in recent years (Powlesland *et al.* 2000), the same approach is likely to ensure the re-establishment of a tomtit population on Chatham Island.

Breeding season

The maximum length of the tomtit breeding season on Rangatira Island was 4.5 months (mid-September to late January), as against 5 months at Pureora, North Island (Knegtmans & Powlesland 1999), 5.5 months on Banks Peninsula, South Island (Kearton 1979), and 4 months on the Snares Islands (McLean & Miskelly 1988). With nest building lasting about 4 days, the pre-lay period 6 days, egg laying 2 days, incubation 17 days, nestling rearing 19 days, and fledglings being dependent for about 25 days, a nesting cycle on Rangatira takes about 73 days. Thus, there is sufficient time for a pair to rear 2 broods in a season if the first clutch is laid in September and they do not have a failed nesting attempt. One pair reared 2 broods on Rangatira during the 1983/84 season (McLean & Miskelly 1988). It is likely that few pairs would achieve such a feat because the earliest clutches are not usually laid until October (Table 1).

The length of the nesting cycle, from start of nest building to chick independence, has been determined as usually 65-73 days for *P. m. chathamensis* (McLean & Miskelly 1988; this study), *P. m. toitoi* (Oliver 1955; Knegtmans & Powlesland 1999) and *P. m. macrocephala* (Oliver 1955; Kearton 1979). However, for *P. m. dannefaerdi* it was greater at about 79 days, largely because this subspecies has a protracted period of fledgling dependence (21-35 days) (Best 1975; McLean & Miskelly 1988). McLean & Miskelly (1988) concluded that the longer nesting cycle of *P. m. dannefaerdi* resulted from its high density (Table 7), and led to the production of fewer, more competitive young.

Nest sites

Tomtits prefer nest sites that provide excellent camouflage and protection from extremes of weather for the nest and its occupants. For example, nests of the 3 subspecies *P. m. macrocephala* (Kearton 1979), *P. m. toitoi* (Brown 1994; Knegtmans & Powlesland 1999) and *P. m. dannefaerdi* (Best 1975; McLean & Miskelly 1988) were in thick vegetation or cavities. Likewise, 90% of 299 *P. m. chathamensis* nests on Rangatira, for which the type of site was indicated, were in or under thick tangles of vines, or in cavities of branches, trunks, or stumps (Table 2). Another possibility for why most *P. m. chathamensis*

nests were in thick vegetation or cavities was as protection from crash-landing seabirds. Over a million pairs of seabirds nest in burrows in the forest on Rangatira (West & Nilsson 1994). Occasionally, black robin and tomtit nesting attempts failed following damage to the nest or its contents by a seabird crash-landing or scrambling up a trunk to fly off (Butler & Merton 1992). It is not known why nest height varied significantly between breeding seasons.

Breeding behaviour

The general description of behaviour of male (regularly feeding his mate during the nest building, pre-lay, laying and incubation stages of the cycle, then regularly feeding nestlings and fledglings) and female (sole charge of nest building, incubating and brooding, and spending time off the nest to accept food from her mate and to forage) tomtits on Rangatira was much the same as that described elsewhere in the literature for the other subspecies (Fleming 1950; Anglesey 1957; Best 1975; Soper 1976; Kearton 1979; McLean & Miskelly 1988; Knegtmans & Powlesland 1999). While detailed information on some aspects of the breeding biology of *P. m. chathamensis* has resulted from this analysis of data from Rangatira (nest site and height, length of pre-laying period, and clutch size), few details exist for some aspects, such as incubation length, hatching and nestling success, and mean productivity pair⁻¹ season⁻¹.

One aspect evident from the analyses of the *P. m. chathamensis* data was the variability in the rate of progress through the nest building and pre-laying stages. Although the mean durations of building and pre-laying stages were 3.4 and 4.6 days, respectively, some females took more than twice as long, particularly early in the season. Similarly, Kearton (1979) found that most females of *P. m. macrocephala* took about 10 days to build their first nests and 6-11 days for the pre-laying stage, but only 3-5 and 1-4 days, respectively, for subsequent nesting cycles. The longer duration of these stages during the first nesting, relative to later in the season, may be related to the shorter daylength and lower temperatures resulting in lower availability of invertebrate prey. Therefore, early in the breeding season both partners may have had to spend more time each day meeting their maintenance requirements than later in the season.

Eggs and clutches

The eggs of *P. m. chathamensis* were similar in colour to those of the other subspecies (Fleming 1950; Kearton 1979). However, they were intermediate in size (19.1 mm × 15.0 mm) between those of *P. m. toitoi* and *P. m. macrocephala* (17.7 + 15.3 and 18.1 + 14.8, respectively) and those of *P. m. dannefaerdi* (20.0 × 15.2) (McLean & Miskelly 1988). It is not known whether this was related to increasing adult size

Table 7 Summary of some aspects of the breeding biology of the New Zealand tomtit (*Petroica macrocephala*).

Subspecies	Location	Mean nesting density (pairs ha ⁻¹)	Clutch size	Nest building (days)	Pre-laying period (days)	Incubation period (days)	Nestling period (days)	Fledgling period (days)	No. of fledged broods
<i>P. m. dannefaerdi</i>	Snares Islands	2.7	2-3	-	-	18-20	17-22	21-35	1
<i>P. m. marrineri</i>	Auckland Islands	-	3	-	-	-	-	-	Up to 2
<i>P. m. chathamensis</i>	Chatham Islands	1.2	2-4	2-8	2-15	17-18	17-21	c. 25	Up to 2
<i>P. m. macrocephala</i>	South Island	0.5	3-5	3-10	1-11	15-17	17-20	18-23	Up to 3
<i>P. m. toitoi</i>	North Island	0.5	3-6	-	-	14-17	17-20	c. 21	Up to 3

Sources: *P. m. chathamensis*, this study, McLean & Miskelly (1988); *P. m. toitoi*, Oliver (1955), Knegtmans & Powlesland (1999); *P. m. macrocephala*, Oliver (1955), Kearton (1979); *P. m. dannefaerdi*, Best (1975), McLean & Miskelly (1988); *P. m. marrineri*, Fleming (1985).

from *P. m. toitoi* to *P. m. dannefaerdi*, or greater parental investment egg⁻¹, chick⁻¹, and/or fledgling⁻¹ with increasing latitude (McLean & Miskelly 1988).

Although the differences were not significant, mean clutch size of *P. m. chathamensis* increased through the season. Such an increase was not found for the North Island robin (*Petroica australis longipes*) (Powlesland *et al.* 2000) or South Island robin (*P. a. australis*) (Powlesland 1983) in both of which clutch size peaked at about the middle of the nesting season.

Nesting success

Compared to 83.5% hatching success and 100% nestling-rearing success of *P. m. chathamensis* during this study, Best (1975) determined 87.0% and 63.9%, respectively, for *P. m. dannefaerdi*. No comparable results are available for *P. m. toitoi* or *P. m. macrocephala*.

Nesting success (proportion of nesting attempts that resulted in at least 1 fledgling each) for *P. m. chathamensis* in 1981/82 was 93%, similar to the 97% noted for *P. m. dannefaerdi* in 1987 (McLean & Miskelly 1988). Neither of these populations is sympatric with introduced mammalian predators. The high success rate compares with 7.7% success for *P. m. toitoi* at Kaharoa (Brown 1997), and 31.3% for *P. m. macrocephala* on Banks Peninsula (Kearton 1979); at both sites introduced predators were present.

Conservation

Black robins, tomtits, and introduced starlings compete for cavity nest sites on Rangatira. Starlings have destroyed robin and tomtit nests and their contents, as well as having killed nesting female robins (Butler & Merton 1992). Given the increasing population of black robins on the island, and that robins often dominate tomtits at nests and feeding sites, tomtit numbers should be checked on Rangatira every few years to ensure this vital, and most secure population, does not decline significantly. In addition, given that Chatham Island tomtits can be studied with little chance of their deserting their nests, researchers on Rangatira and Mangere Islands working on other projects should be encouraged to monitor tomtit nests when possible to obtain data on little-known aspects of the breeding biology, such as length of incubation, nestling, and fledgling periods, and nesting success.

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