Notornis , 2001, Vol. 48: 207-216
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Status and breeding biology of the Chatham Island tomtit (*Petroica macrocephala chathamensis*)

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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.

Powlesland, R.G.; Merton, D.V.; Crouchley, D.; O'Connor, S. 2001. Status and breeding biology of the Chatham Island tomtit (*Petroica macrocephala chathamensis*). *Notornis 48 (4)*: 207-216.

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

Received 29 September 2000; accepted 17 April 2001

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 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).

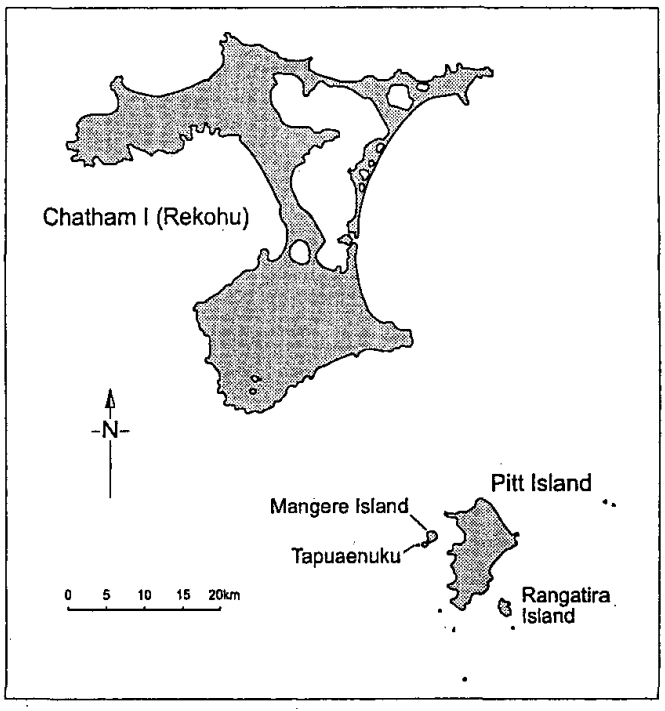

Fig. 1 Chatham Islands group showing the location of each island mentioned in the text.

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 assumed 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.).

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.

	Laying date	
Season	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

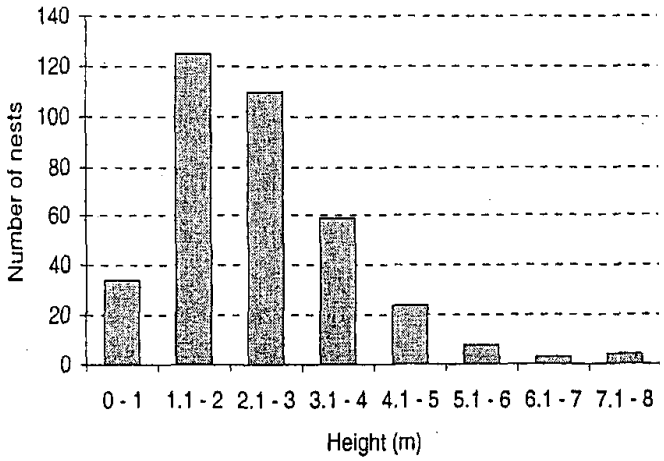

Fig. 2 Number of Chatham Island tomtit (*Petroica macrocephala chathamensis*) nests (n = 370) found on Rangatira Island during 1981-89 in various height categories.

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 materials 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 + length + 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			
	2-egg	3-egg	4-egg	Mean
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					
	1	2	3	4	5	Mean
Nest building	6	-	-	-	-	1.0
Prelay	-	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, prelay, 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 x 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)	Prelaying period (days)	Incubation period (days)	Nestling period (days)	Fledgling period (days)	No. of fledged broods
P. m. dannefaerdi	Snares Islands	2.7	2-3	-	-	18-20	17-22	21- 35	1
P. m. marrineri	Auckland Islands	-	3	-	-	-	-	-	Up to 2
P. m. chathamensis	Chatham Islands	1-2	2-4	2-8	2-15	17-18	17-21	c. 25	Up to 2
P. m. macrocephala	South Island	0.5	3-5	3-10	1-11	15-17	17-20	18-23	Up to 3
P. m. toitoi	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.

ACKNOWLEDGEMENTS

Our thanks to the following people who are known to have contributed to the data available on tomtit nest-record sheets for Rangatira: Mike Aviss, Derek Brown, Jeremy Carroll, Bill Cash, David Cemmick, Rob Chappell, Phil Clerke, Andy Cox, Alison Davis, Raewyn Empson, Andrew Grant, Euan Kennedy, Sandy King, Graeme McArthur, Pete McClelland, David Merton, Margaret Merton, Nigel Miller, Allan & Ngaio Munn, Geordie Murman, Ron Nilsson, Mary Powlesland, Alan Tennyson, Rick Thorpe, Tertia Thurley, Dick Veitch, and Paula Wilson; to Mike Bell for information on the status of *chathamensis* on Tapuaenuku and for tomtit weights, to Sandy King for the results of 5-minute forest bird counts undertaken on Pitt Island, to Brian Gill for providing measurements of Chatham Island tomtit eggs held at Auckland Museum; to Alan Tennyson for making the entire collection at the Museum of New Zealand available for measurement; and to Mike Dennison, Peter Dilks, Jaap Jasperse, Sandy King, Colin Miskelly, and 2 referees for improvements to drafts of this paper.

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