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Population status, breeding and ecology of Chatham Island tui (*Prosthemadera novaeseelandiae chathamensis*)

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Abstract Status, breeding, and foraging of Chatham Island tui (*Prosthemadera novaeseelandiae chathamensis*) were studied on Rangatira Island, Chatham Islands between January 1995 and May 1999, with short visits made to adjacent Pitt Island throughout this period. The total population was estimated at ≈260 adults. Most birds were resident on Rangatira Island in spring, summer and autumn but moved to Pitt Island during the winter. In spring birds commuted between the two islands but became resident on Rangatira when breeding commenced. Radio transmitters were attached to adult tui to monitor breeding. No radio-tagged female bred (n = 13) but at least two of three radio-tagged males raised young. Adult tui were intolerant of disturbance during nesting so estimation of productivity was made by mapping the number of fledgling groups. Flax (*Phormium tenax*) nectar appeared to be the most important food for breeding tui and birds travelled long distances to visit flowering plants. Fruits of ngaio (*Myoporum laetum*), matipo (*Myrsine chathamica*), karamu (*Coprosma chathamica)*, mahoe (*Melicytus chathamicus*) and muehlenbeckia (*Muehlenbeckia australis*) were also important foods. Invertebrates were most important when females were feeding their young. The amount of breeding that occurred each season was directly related to the abundance of flax flowers in spring, and in good flax flowering years tui were able to rear two broods. In poor flax flowering years many birds did not breed. Control of feral cats on Pitt Island would most likely result in a significant increase in this breeding population; however planting of flax adjacent to the forest areas on Chatham Island along with predator control may be necessary before tui can re-establish there.

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Keywords Chatham Islands; tui; *Prosthemadera novaeseelandiae chathamensis*; breeding; seasonal movements; diet.

INTRODUCTION

Chatham Island tui (*Prosthemadera novaeseelandiae chathamensis*) is an endemic subspecies of the New Zealand tui (*P. n. novaeseelandiae*). It was formerly widespread and common on all of the major islands of the Chatham group: Chatham, Pitt, Rangatira and Mangere Islands (Figure 1). The tui is the only honeyeater remaining on the Chatham Islands since the endemic bellbird (*Anthornis melanura melanocephala*) became extinct in about 1906 (Turbott 1990).

By 1938 the tui's range and numbers had been much reduced (Fleming 1939). They were, then, less common in the north of Chatham Island but plentiful in the more forested southern parts, abundant on Pitt Island, and in "fair numbers" on Rangatira Island (Fleming 1939). Their decline continued and by the 1970s tui were reported as uncommon on Pitt and Chatham Islands (D. Merton, B.Bell unpubl. data) although they were still breeding in low numbers in the south of Chatham Island (H. Robertson pers. comm.). A survey of most of the forested areas on Chatham Island in 1988 and 1989 recorded tui in only 18 of 446 one-kilometre map squares visited and in almost all instances only a single bird was recorded (A. Grant pers. com.). During research on parea (*Hemiphaga novaeseelandiae chathamensis*) in the south of Chatham Island in the early 1990s (Powlesland *et al*. 1997), a few tui were seen, usually in winter, but in summer it was extremely rare to see any (pers. obs.).

On Pitt Island tui numbers have declined greatly and there is now marked seasonal variation in their abundance. During a botanical survey of reserves in April 1983 few tui were observed (G. Walls pers. comm.), but in spring 1994 large numbers of birds were observed feeding on flowering flax (*Phormium tenax*) (A. Turner pers. comm.).

Tui have always been recorded from Rangatira Island but numbers were low when the island was grazed. For example, tui were recorded as rare in 1953 (Bell 1955), seen occasionally in 1954 (Dawson 1955), and 10-12 pairs estimated in 1961 (D. Merton, B.Bell unpubl.data). However, since grazing ceased in 1961 the vegetation has recovered and tui numbers have increased markedly. Tui were the second most conspicuous species recorded during bird counts on Rangatira Island in 1983 (West

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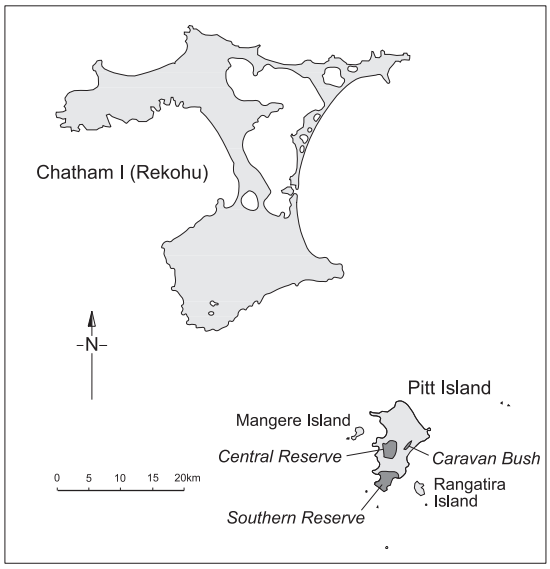

Figure 1 Chatham Island group and locations of reserves on Pitt Island.

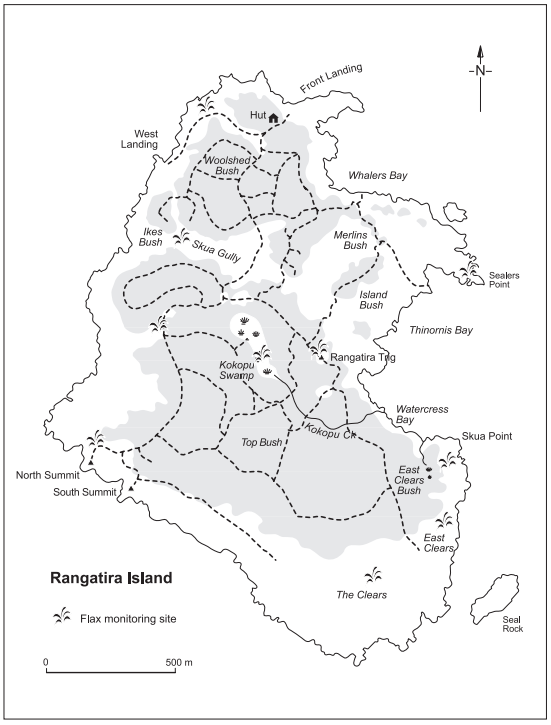

Figure 2 Rangitira Island, place names mentioned in the text, and the locations of the flax monitoring sites. The shaded area shows the extent of forest cover.

1988), and they were recorded as abundant in the 1990s, with a flock of 60+ birds seen in the air over Woolshed Bush (Nilsson *et al*. 1994). Few tui have been observed on the largely deforested Mangere Island but birds occasionally visit and a pair has bred there recently (D. Fastier pers. comm.).

Tui are now common only on Rangatira Island, and although birds are seen regularly on adjacent Pitt Island, particularly outside the breeding season, it seems that most of the breeding population is on Rangatira Island.

There is no current information on the status of the Chatham Island tui and little is known of its ecology. The aims of this study were: 1. to determine the current status and trends of the tui population on Rangatira Island; 2. to determine the relationship between the Rangatira and Pitt Island tui populations, and the importance of these habitats to the overall population; and 3. to describe foraging and breeding success, and investigate if habitat enhancement could assist tui return to areas of their former range from which they have vanished.

STUDY AREAS

The Chatham group comprises one large island, Chatham Island, with a group of smaller islands to the south-east. Pitt Island (44°20′ S, 176°10′ W) is located approximately 27 km south-east of Chatham Island, and Rangatira Island is located 2.5 km off the south-east coast of Pitt Island (Fig. 1). The climate of these islands is mild, windy and cloudy (Thompson 1983).

Rangatira (South East) Island

Rangatira Island (218 ha) is the third largest island in the Chatham group and is of volcanic origin. It slopes gently from near sea level at the northern end to a high point of 224 m above steep cliffs at the south end (Fig. 2). There are no introduced mammals on Rangatira.

Until the island became a reserve in 1954 it was farmed and held sheep, cattle and goats. The last sheep were shot between 1956 and 1961 (Veitch & Bell 1990) and since then the vegetation has regenerated rapidly. The former extensive areas of pasture are now mostly covered with bracken (*Pteridium esculentum*) and muehlenbeckia (*Muehlenbeckia australis*) with small pockets of regenerating forest trees. There are two large areas of forest: Woolshed Bush at the lower north end of the island and the bigger Top Bush centred on the catchment of Kokopu Creek. The main forest trees are ribbonwood (*Plagianthus betulinus* var. *chathamica*), ngaio (*Myoporum laetum*), akeake (*Olearia traversii*), matipo (*Myrsine chathamica*), karamu (*Coprosma chathamica*), mahoe (*Melicytus chathamicus*) and hoho (*Pseudopanax chathamicus*), with kawakawa

(*Macropiper excelsum*) and supplejack (*Ripogonum scandens*) common in the understorey. Flax is widespread round the coastal cliffs, especially in "The Clears" at the southern end of the island.

Pitt Island

Pitt Island (6325 ha) is the second largest island in the Chatham group and is extensively farmed, with most of the northern half of the island consisting of pasture-covered rolling hills. The southern half of the island has three large forested reserves: the Southern Reserve, the Central Reserve and covenanted Caravan Bush (Fig. 1). Forest tree species are similar to Rangatira but with more hoho and kopi (*Corynocarpus laevigatus*), and in addition, hokotaka (*Corokia macrocarpa*), widespread tarahinau (*Dracophyllum arboreum*), and extensive groves of nikau (*Rhopalostylis sapida*) in the Central Reserve. The coastal slopes of the Southern Reserve have extensive areas of flax with smaller areas found along the eastern cliffs of the Island.

All of the reserves are fenced to keep out domestic stock but large numbers of sheep and moderate numbers of feral pigs graze the Central Reserve. The Southern Reserve has pigs present but no sheep. Caravan Bush has no grazing animals present. Feral cats (*Felis catus*) are found throughout Pitt Island; these, mice (*Mus musculus*) and weka (*Gallirallus australis hectori*) are the only other introduced animals found on Pitt Island that may have an impact on tui.

METHODS

Field study periods

The study commenced in January 1995, was followed by a short visit the next summer, and thereafter by tui researchers being present on Rangatira Island between November and March in 1996/97, 1997/98 and 1998/99. Short visits of 3 - 10 days were made to Pitt Island during the breeding seasons of 1996/97 and 1997/98, and winter visits were made to Pitt and Rangatira Islands during 1996 and 1997.

Capture

Tui were caught using mist-nets (Dilks *et al.* 1995). Most birds were caught at flowering flax plants where birds were feeding on nectar; or at streams and ponds where birds came regularly to drink and bathe. During breeding, when birds were strongly territorial, some were caught in low nets erected within the forest to which they were attracted by recorded tui song and distress calls. One brood of nestlings was banded in their nest. No birds were banded on Pitt Island.

Banding, aging and sexing

All birds caught were banded, weighed and measured before being released and most were given an individual band combination using three colours and a metal band.

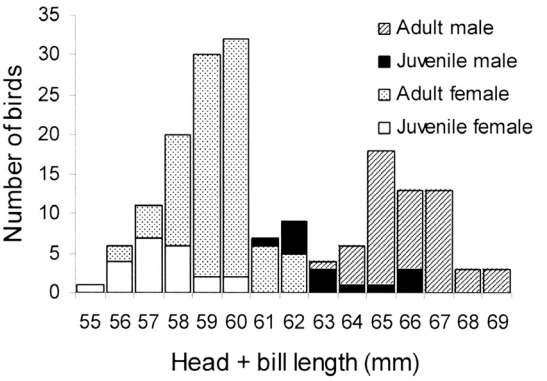

Figure 3 Distribution of wing lengths of Chatham Island tui caught on Rangitira Island (n = 177). Juveniles include birds in their first year of life that have retained their juvenile primaries.

Birds were aged and sexed following Olney (1986). They were separated into juveniles/first-year birds or adults by the absence of a wing notch in younger birds, and sexed by wing length (Fig. 3). Birds could also be sexed using head plus bill length; adults and first-year birds with a head bill length greater than 62 mm were males.

Food availability

Previous studies on tui diet had found that nectar and fruit were the most important foods (Bergquist 1985a; Gravatt 1969) so plant species providing nectar and/or fruit were monitored through the summer. Permanent plots were set up in areas of flax to monitor flax flowering (Fig. 2). Distinct clumps of flax plants that could be easily identified from year to year were chosen and the number of flower spikes produced each year was recorded. This monitoring was repeated at intervals from late October until early January when no flowers remained. Flax spikes were classed as 'flower" so long as they had some flowers providing food to tui. Three plots were also established on Pitt Island.

Forest plant foods (flowers and fruit) were monitored along three transects set up along the island's tracks. An observer walked along and recorded the numbers of each plant species that had flower buds, flowers or fruit present. This gave a coarse indication of foods available to tui and was designed to show if there were large differences in available foods between seasons and years.

Diet

Diet was recorded following Powlesland *et al.* (1992): every time a bird was encountered the food type,

Table 1 Chatham Island tui caught on Rangatira Island ([1] 2 females in 96/97 and 5 males in 98/99 were not aged).

Year	1994/95	1995/96	1996/97	1997/98	1998/99	Total
Adult male	11	5	25	4	8	53
1 year male	4	-	3	-	2	9
Juvenile male	12	-	6	3	1	22
All males	27	5	34	7	16[1]	89[1]
Adult female	22	6	37	5	8	78
1 year female	3	4	7	3	4	21
Juvenile female	8	-	6	5	5	24
All females	33	10	52[1]	13	17	125[1]
Nestlings	-	-	3	-	-	3
Total	60	15	89	20	33	217

plant species and location of the bird in the forest was recorded. Seeds found in faeces or regurgitated by birds during banding were also identified and noted.

Radio tracking
In an attempt to find nests, monitor movements and record mortality of tui, radio transmitters were attached to some birds and the birds tracked using a Telonics TR4 receiver and hand-held aerial. Initially, radio transmitters were attached with a thin cord harness (backpack transmitter), and later by attaching a smaller transmitter to three central tail feathers using dental tape and glue. Backpack transmitters weighed ≈4 g and lasted 14 months. Tail-mounted transmitters weighed 1.4 - 2.75 g and lasted between 100 days and 9 months.

Breeding
The onset of tui breeding was detected by monitoring the birds' behavioural changes. Some nests were found by following birds carrying nest material and others by radio-tracking adults. Intensive searches were made for tui nests in areas where adults were regularly seen. Some nests were also found incidentally, and others by following birds returning to their nest to incubate eggs or feed nestlings. Searching for, and mapping the ranges of, newly-fledged tui broods was also used to monitor the distribution of breeding pairs and the extent of breeding each year.

Population estimate
To estimate population size, the whole island was surveyed by walking all of the tracks and stopping at *c.*100 m intervals to play recorded tui calls. Birds that responded to the calls and could be seen were recorded as banded or unbanded; those that were not seen clearly were recorded as "unidentified". The population size was estimated using the Lincoln Index "mark-recapture" method (Davis & Winstead 1980). The Lincoln Index assumes a closed population, so to minimize any error due to death or emigration of banded birds only information on birds banded in the current season was used.

Pitt Island observations
Only short visits were made to Pitt Island, usually as part of getting to and from Rangatira Island. Whenever possible, visits were made to all of the main forest areas on Pitt Island and surveys carried out to get an indication of the number of birds present and the extent of breeding.

RESULTS

Population structure
Between January 1995 and April 1999, 217 tui were caught (Table 1). Although equal numbers of juvenile males and females were caught (22:24), there was a large sex imbalance in numbers of adults caught: significantly more adult females (99) than males (62) were caught (Exact binomial test $p = 0.004$).

Seventy-nine (39%) of the birds were of known age – banded either as young-of-the-year or as one-year-olds. The percentage of one-year-old birds caught varied from year to year with the highest portions caught the year after good flax flowering, and presumably good breeding summers.

Morphology
Chatham Island tui are considerably larger and heavier than New Zealand tui (Table 2). Weights of some tui varied between seasons with birds gaining considerable weight during autumn/winter. One male that was first caught on 11 January 1995 weighed 160 g but when re-trapped on 3 August 1995 weighed 238 g. The one male caught in May 1996 weighed 240 g and two females weighed 159 and 170 g, considerably heavier than the average summer weight.

Table 2 Comparative measurements of adult Chatham Island tui from Rangatira Island and adult New Zealand tui from Orongorongo Valley, Wellington (Robertson et al. 1983) and Tiritiri Matangi Island and the adjacent mainland, Auckland (Craig et al. 1981). Rangatira Island weights are for summer only.

		Rangatira Island		Orongorongo Valley		Auckland
		mean	range	mean	range	mean
Weight	Male	154.4	137-198	124.9	97-150	121.2
(g)	Female	111.8	89-164	89.6	70-105	87.0
Wing	Male	159.8	150-171	152.2	142-163	144.2
(mm)	Female	141.5	135-147	133.2	125-142	129.3
Tarsus	Male	44.9	42.4-48.9	40.9	38-44	-
(mm)	Female	40.6	38.7-48.8	37.0	32-40	-
Tail	Male	132.5	123-155	122.3	104-134	-
(mm)	Female	119.1	111-132	108.8	100-117	-

Seasonal movements of birds

Few tui were present on Rangatira Island in August 1995. Cold south-westerly winds, hail and sleet made it then a bleak place. Tui then observed were "fluffed up" and appeared lethargic while those seen on Pitt Island a few days earlier appeared normal. Kakariki (*Cyanoramphus novaezelandiae*) observed at the same time appeared weak and had difficulty flying or feeding on the forest floor. A freshly dead parakeet appeared to have starved.

The winter absence of tui on Rangatira Island, and their subsequent presence in spring, indicates that a large proportion of Rangitira Island's tui population departed to over-winter on Pitt Island. The timing and extent of departures probably varied in response to food, particularly fruit, available on Rangatira Island in winter. A large portion of the vegetation comprises *Muehlenbeckia* vines which often lose most of their leaves due to wind-blown salt spray, and ribbonwood forest which is deciduous. As a result the shelter and food supply afforded by the forest was much reduced in winter.

Tui returned to Rangatira Island in spring to breed. Initially birds may have commuted between the islands. For example, in October/November birds were observed both flying to and from Pitt Island; the largest group seen comprised 15 birds probably leaving to feed on flax on Pitt Island, which started flowering earlier than on Rangatira (pers. obs.). Some birds regularly commuted between Rangatira and Pitt Islands, spending a few days at each but stayed on Rangatira Island whilst breeding.

In January 1996 both radio-tagged breeding males flew to Pitt Island as soon as their nestlings had fledged, leaving the female with the young. Radio-tagged females followed later. However, some birds that were radio-tagged in early 1999 remained on Rangatira Island until at least May when their transmitters failed. Two colour-banded birds were known to have moved to Pitt Island and to have established territories and bred there.

In late summer, flocks of tui congregated in forest on the north-west side of Rangatira Island, the point closest to Pitt Island, and at intervals set off across the sea. During strong north-westerly winds birds would struggle into the wind, often making little progress before being blown back and later making further attempts.

All radio-tagged birds that were tracked after they left Rangatira Island in late summer and autumn were found in the Central Reserve on Pitt Island. Earlier in the summer, when flax was flowering, some radio-tagged birds were visiting the flax-covered slopes at the south end of Pitt Island.

Food availability

Forest phenology

There was large variation in the extent of flowering and fruiting between years and among individual trees of the same species. Ngaio was the only species in which almost all trees had either fruit and/or flowers at the same time. Matipo fruiting was especially variable, with a few trees heavily laden with fruit and many trees with few or none.

Flax flowering

Flax nectar was the most important food for breeding tui . There was a large variation between years in the number of flax flowers recorded on plots (Fig. 4). The length of the flax flowering period varied at different sites on the island with the exposed sites at the island's summit having later and shorter flowering periods. The more sheltered and lower altitude sites, such as Sealers Point, had earlier and longer flowering periods. During good flax flowering years, flowers (nectar) were available from mid-October until early January, but in poor flowering years flowers were present for a much shorter period.

Tui diet

When flax nectar was available, it was the most important food for tui. Large numbers of birds

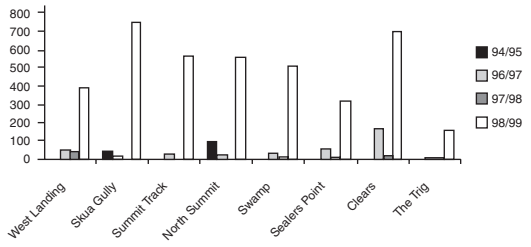

Figure 4 The number of flower stalks on monitored flax bushes (a measure of abundance of flax flowers) within flax plots on Rangitira Island 1994/95 – 1998/99. Only two plots were established in 1994/95 but eight in each subsequent year.

congregated at flowering flax and individual birds commuted throughout the day to and from flax plants. One distinctive female was monitored for much of one day: between 1100 - 1800 hrs she made 10 visits, feeding for 8 - 20 mins each time. The mean interval between her visits was 42 mins (range 22 - 50 mins). When flowers were abundant, each bird had its own area and specific flax plants which they defended against other tui. As flax nectar became scarcer birds would travel to the remaining flowering plants from all parts of the island.

Matipo, karamu and hoho fruit were other important foods and were eaten when green or ripe (Table 3). Matipo and karamu are widespread on Rangatira Island but there are only small numbers of large fruiting hoho trees. Individual birds appeared to spend long periods of time in particular matipo trees; some radio-tagged females were found regularly in the same trees.

Ngaio was also an important food source and birds fed on nectar from flowers and ate green and ripe fruit. They also licked sap from bruised and broken branches. *Muehlenbeckia* vines covered extensive areas of the island and their fruit was an important food also. Female tui often gathered muehlenbeckia fruit when feeding chicks.

Birds that were feeding nestlings were often observed perched at vantage points from where they caught insects in muehlenbeckia foliage or hawked for insects in the air. All seven birds caught by mist netting in one of these areas were females. At times groups of birds would hawk for insects high above the forest canopy.

During winter (May - August) ngaio fruit was the most important food but the few fruiting hoho trees all had resident tui. Birds were also observed searching kawakawa for ripe fruit.

Monitoring movements and breeding by radio tracking

In November 1995 and 1996 none of 10 females wearing transmitters nested, although breeding by other tui was widespread. In contrast, at least two, possibly all three, of the radio-tagged males bred successfully.

These birds wearing transmitters were initially most often recorded as resident in discrete territories even though most did not breed, but later in the breeding season could be found anywhere on Rangatira Island. Initially the two males regularly flew to Pitt Island and stayed there for one - five days but when they started breeding they stopped visiting Pitt Island. However, as soon as their young fledged they returned to Pitt Island, and only occasionally re-visited Rangatira Island.

In contrast, radio-tagged female tui remained on Rangatira Island throughout the breeding season even though they did not nest. Each was regularly found in a very small home range area, often in the same tree, usually a fruiting matipo. None of these birds attempted to nest although five of the six had a developing brood patch when initially caught. One female had the same summer territory in two breeding seasons.

During the 1997/98 breeding season four female tui carried radios but none nested, although they all had developing brood patches when caught. This summer was a poor flax flowering year and tui breeding was spasmodic. Two of these females visited Pitt Island during November.

Juveniles carrying radio-transmitters in 1998 and 1999 wandered widely around the upper part of Rangatira Island. In 1999 three of nine birds followed for four weeks visited Pitt Island with two returning to Rangatira Island. One bird regularly commuted between the islands.

Breeding

In mid-October when field-work commenced, birds on Rangatira Island showed no signs of breeding and males were still visiting Pitt Island. The females remained in small, discrete territories and frequently visited flax plants several hundred metres away to feed. No breeding behaviour was observed until November when display flights, territorial boundary squabbling and nesting commenced.

Nest monitoring

Ten nests were found. In four nests, found when the adults were feeding young, all chicks fledged successfully. However, four of six nests found while being built or containing eggs were immediately deserted, one was destroyed by wind and one produced fledglings. Tui proved to be very intolerant of any intrusion during at least the early stages of breeding and most birds would not return to their nest while being observing.

Nests were two - six metres above ground and usually built in areas of thick cover, often amongst dense *Muehlenbeckia* vines where they could not be easily seen from the ground.

Table 3 Number of observations of tui feeding on various foods on Rangatira Island. Most observations of birds feeding on flax flowers were not recorded. (* feeding on honeydew on branches.)

Plant species	Sap	Flower/nectar	Fruit	Invertebrate	Total
Flax	-	186	-	1	187
Matipo	-	-	147	2	149
Ngaio	16	22	53	2	93
Muehlenbeckia	-	-	80	2	82
Kawakawa	-	-	65	3	68
Karamu	-	-	36	2	38
Olearia	1	-	-	20	21
Ribbonwood	2	-	3	13	18
Mahoe	-	-	11	-	11
Hoho	2	-	3	-	5
Supplejack	-	-	4	-	4
Hebe	-	3	-	-	3
Tarahinau	-	3*	-	-	3
Iceplant	-	2	-	-	2
Ground	-	-	-	1	1
Aerial	-	-	-	5	5
Overall	21 (3.0%)	216 (31.3%)	402 (58.3%)	51 (7.4%)	690

From the five successful nests observed, brood size varied between one and four. Of 39 other broods observed in 1997, 18 comprised two fledglings, five a minimum of two fledglings, six were of three fledglings, and 10 broods comprised at least one fledgling.

At two nests in January 1995, feeding of the nestlings appeared to be carried out entirely by the female. At times the male accompanied the female to the nest and sang from a nearby perch. A nest with three nestlings about one week old was observed for three hours on 23 January 1995; 53 feeding visits were made in 180 mins and, at times the female was visiting at less than one-minute intervals with *Muehlenbeckia* fruit from vines near to the nest. At another nest 36 feeding visits were made over 120 mins.

Fledgling monitoring

After chicks had fledged they usually remained near the nest area for about two weeks, often sitting close together and calling constantly. Parent tui were especially defensive of newly-fledged chicks and scolded observers approaching the chicks at close range.

In 1996/97 the first fledglings were found on 21 December, and family groups were apparent until mid-January. In total 41 family groups and at least 74 fledglings were recorded (Table 4). For those broods where all young were thought to have been observed, the mean brood size was 2.25 fledglings.

In 1997/98 flax flowering was poor but in 1998/99 flowering was extremely heavy. This was reflected in the number of fledgling groups counted (Table 4). In 1997/98 the first fledglings were observed on 28 December and in 1998/99 on 16 December.

In 1998/99 some pairs rearing two broods and it is likely that double brooding was widespread. Tui fledglings were first recorded in mid-December and another "wave" of newly fledged young was observed late in January.

Population size estimates

In 1994/95 two population estimates were made using the Lincoln Index method (Davis & Winstead 1980). Using resightings of adults only produced a population estimate of 237 birds ± 120; using observations of all banded birds, the estimate was 432 birds ± 206.

Juveniles were much less mobile than adult birds and including them may have produced a less realistic population estimate.

Estimation was repeated during the 1998/99 summer using only sightings of adult birds banded in 1998. The resulting population estimate was 278 birds ± 62.

Pitt Island observations

During May 1997, tui were present in all areas visited but few birds would have been seen had recorded calls not been played. Of 141 tui encountered, 71% were in the Central Reserve. Groups of up to 14 birds were attracted by the calls and similar-sized groups were seen feeding on ripe hoho fruit. Most tui seen were probably juveniles because, on Rangatira Island, adult tui completely ignored taped calls at this time of year.

All radio-tagged birds followed on Pitt Island for extended periods were resident in the Central Reserve. Some recorded commuting between the islands in spring spent periods of time at the

Table 4 Number of groups of fledgling tui recorded on Rangitira and Pitt Islands

Year	Fledgling groups on Rangatira	Number of fledglings on Rangatira	Fledgling groups on Pitt
1996/97	41	74	6
1997/98	21	34	3
1998/99	72	120	Not searched

Southern Reserve, which has extensive areas of flax on the coastal cliffs.

Tui distribution and breeding on Pitt Island

In late January 1997, forested areas were surveyed for tui and signs of breeding (fledglings). Only six broods of fledglings were found; two in the Southern Reserve, one in Central Reserve and four around Caravan Bush/North Head area (Table 4). More adult tui were seen, and from their distribution it was estimated that there were 25 pairs of tui resident on Pitt Island.

In December 1997, the forest areas were again searched for breeding tui. This was a poor breeding year on Pitt Island as it was on Rangatira Island. Only two breeding pairs were found, one feeding nestlings in the Southern Reserve and another with a fledgling at North Head. However, we saw three pairs nest prospecting, and another brood of fledglings was found at one of these sites later in the season. From the distribution of birds we again estimated there were 25-30 pairs of tui present.

DISCUSSION

Capture, banding and radio-telemetry

The higher numbers of female tui caught may reflect a sex imbalance in the population, or simply a bias in the catching method. Male and female tui are considered equally likely to feed on flax nectar and to visit drinking/bathing areas, yet many more females were caught at water. There was no indication that males were more wary and less likely to be caught. However, most tui were caught at water in late summer (January and February); the fewer males caught may reflect male tui leaving Rangatira Island for Pitt Island as soon as nestlings have fledged. Numbers of males and females caught at flowering flax in November/December at the start of the breeding season were similar.

Radio telemetry proved useful for monitoring movements of birds around and away from Rangatira Island but, as a tool for monitoring breeding and foraging, it was a failure as it appeared to discourage female tui from breeding. It is highly unlikely that, by chance, only female tui that were not going to breed were radio-tagged, as most had developing brood patches when caught. Also there was widespread breeding on Rangatira Island and two, possibly all three, of the radio-tagged males bred. Radios attached by harnesses did not appear to restrict the mobility of birds, as they ranged widely over Rangatira Island, commuting to and from distant flax flowers and on many occasions flew back and forth across the 2.5 km of sea to Pitt Island. A female that was recaptured and had its transmitter removed after wearing it for just over two months had gained a little weight (128 g *c.f.* 120 g).

Diet

Unbiased data on the diet of tui proved difficult to obtain. Following birds in the forest was almost impossible and tui could be readily observed only in the more open areas of flax and muehlenbeckia, or at known fruiting trees. Therefore, the resulting feeding observations (Table 3) are only an indication of their diet and the range of foods eaten.

Birds were observed licking the branches of several plant species, especially ngaio, and were probably feeding on sap from damaged branches. Only a few plant species were recorded as nectar sources, and it is likely that more species, notably mahoe and hoho, were also used, but birds were difficult to observe in areas where these trees were common.

The diet recorded for New Zealand tui is very different; nectar was its most important food, comprising between 81% and 97% of observations in three studies (G. Angehr unpubl. data; Bergquist 1985a, 1985b; Gravatt, 1969). During spring and early summer on Rangatira Island whilst flax was flowering, nectar certainly was the major component of the tui diet. However, in some years there were very few flax flowers and they were quickly destroyed by kakariki feeding on them. In these years nectar would be a small dietary component for tui. The number of tui breeding was clearly associated with the intensity of flax flowering, and abundant flax nectar seems to enable more birds to reach breeding condition.

During this study some breeding occurred each year. Observations of dead and dying juvenile tui (P. Gardener pers. comm.) suggests that, in some years, food may be limiting in autumn, forcing many tui fly to Pitt Island for the winter. On Chatham Island the amount of fruit present varies considerably between seasons and years. For example, hoho and matipo can be especially variable and both have fruit that are high in food value (Powlesland *et al*. 1997). Abundant fruit in autumn and winter would be important for over-winter survival and recruitment of juveniles into the population.

On Pitt Island most of the tui were found in the Central Reserve, which had the most diverse forest and largest numbers of hoho trees (pers. obs.). There were also extensive areas of tarahinau forest in this reserve and in some areas these have scale insects that produce honeydew. This has been found to be an important food source for tui in New Zealand (Gaze & Clout 1983). Honeydew is produced year-round and may be an important winter food for Chatham Island tui.

Observations on radio-tagged birds suggest that until flax flowering was well underway on Rangatira Island, birds commuted to Pitt, presumably to feed on more abundant and earlier flowering flax there. Both of the breeding males with functioning transmitters left for Pitt Island in early January soon after their chicks had fledged, again indicating that food may be more abundant on Pitt at this time.

Breeding

The start of breeding varied between years. Juvenile tui were first caught early in January 1995 but were not caught until two weeks later in January 1997. Detailed monitoring of tui breeding proved difficult because females were very intolerant of disturbance during the early stages of breeding. Tui nests were well hidden in thick *Muehlenbeckia* vines draped over forest trees and proved difficult to discover by random searching. A possible reason for such well-concealed nests amongst thick cover is that every night during the summer tens of thousands of sea birds returning to the island crash through the forest canopy returning to their breeding burrows. Nests in more open locations would be more prone to being hit by a returning sea bird. This behaviour of nesting amongst thick cover has also been recorded for Chatham Island tomtits on Rangatira Island (Powlesland *et al*. 2001).

The tui population on Rangatira Island has increased markedly since 1961 when only 10-12 pairs were estimated to be present on the island (D. Merton unpubl. data). This large increase is almost certainly in response to the recovery in the island's vegetation since grazing animals were removed.

Pitt Island

Although Pitt Island has much larger areas of apparently suitable tui habitat, it has a smaller breeding population than Rangatira Island, perhaps only 25-30 pairs. Tui are known to return to the same area to breed each year and young birds often breed close to their natal sites (Bergquist 1985b, Stewart & Craig 1985). If Rangatira Island was the source of most of the remaining tui, then they and their offspring would be more likely to return there to breed.

Pitt Island seems to be an important winter habitat for most of the Chatham Island tui's population and few birds remained on Rangatira year-round. The forests of the Central Reserve on Pitt had the highest numbers of large hoho trees of any forests on Rangatira or Pitt Islands, and in good years fruit was available from April until spring. Large hoho trees can produce tens of thousands of fruit and would provide an important winter food source. Karamu and matipo, other important winter food trees, were also abundant in the Central Reserve. Pitt Island may also provide a vital early nectar source for tui that enables them to reach breeding condition earlier in prolific flax flowering years.

A few of the birds banded on Rangatira Island were found breeding on Pitt Island; as suitable habitat on Rangatira fills up, more birds might migrate to Pitt Island. The forest habitat on Pitt Island appears very suitable for tui, and all the important food species that are found on Rangatira Island are more abundant on Pitt Island. There are also several other species on Pitt Island that provide fruit and nectar supplies (nikau and hokotaka).

Feral cats are widespread on Pitt Island and cat predation could be an important limiting factor for tui there. The open grazed forests of the Central Reserve provide ideal conditions for cats. A cat den found in Caravan Bush contained tui remains amongst other prey items, yet tui are only found in low numbers in this area (S. King pers. comm.).

The future

The Chatham Island tui population probably fluctuates in response to good and bad flowering and fruiting years. The forests on Rangatira Island may be reaching carrying capacity as tui are common in all forests on the island and some birds hold territories in seemingly marginal habitat comprising small groups of trees and large areas covered with muehlenbeckia vines. With only one significant population, on Rangatira Island, this leaves Chatham Island tui very vulnerable to an unforeseen event such as habitat loss due to fire, or predators reaching Rangatira Island.

In the short to medium term, Pitt Island has the greatest potential for a further increase in tui numbers. A sustained cat control program on Pitt Island would most likely result in a marked increase in numbers. Control of the feral sheep and pigs in the Central Reserve would allow recovery of the forest structure and improve the forest for tui. Regeneration of a dense understorey would also provide less favourable conditions for feral cats.

It is likely that the extinction of tui as a breeding species on Chatham Island had several causes. Habitat loss must been a major factor in their decline, and until recently, feral sheep, cattle, pigs and possums (*Trichosurus vulpecula*) were ravaging the island's remaining forest remnants. The presence of possums, feral cats, weka and all three species of rats (*Rattus* sp.) would have taken a toll

on any breeding birds. Although tui can be found successfully co-existing with all of these species on mainland New Zealand, on the Chatham Islands the forest is mostly less than 20 m tall, with a simple structure. Any tui nest would have a good chance of being found by possums, rats or cats.

As nectar is an important food during the breeding season, the decline of tui could have been exacerbated by the reduction in nectar sources. On Chatham Island, as forest areas were reduced by land clearance, the health of the remaining habitat was reduced by possums browsing the forests and cattle eliminating much of the nearby flax. In the southern area of Chatham Island where tui were last recorded breeding, little flax remains apart from small areas on the coastal cliffs. The fencing of reserves on Pitt Island and the re-invasion of the Southern Reserve by large areas of flax, along with the recovery of flax following stock removal from Rangatira Island, may have been a major factor in the recovery of the Rangatira/Pitt Island tui population.

On the southern end of Chatham Island extensive cat and possum control is undertaken to protect breeding taiko (*Pterodroma magentae*), and if this was extended to include the best tui habitat in the lower Tuku and Awatotara Valleys then a reintroduction of tui to these areas could be contemplated. The likelihood of a successful reintroduction would be increased by planting of extensive areas of flax in advance to provide what appears to be a vital food supply for breeding birds. Re-establishment of tui onto Chatham Island would create a third tui population, provide more security for the future of the species, and contribute towards re-establishment of the original bird fauna on Chatham Island.

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