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Use of radio telemetry to determine home range and movements of the bellbird (*Anthornis melanura*) – a feasibility study

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Abstract Radio transmitters were successfully attached to 7 male bellbirds (*Anthornis melanura*) in Kennedy's Bush and Cass Peak Reserve, Port Hills, Christchurch, during the breeding season. A hand-held radio receiver was used to relocate them. In addition, we used a grid of 4 remote continuously-operating proximity sensors (radio receivers connected to data loggers) to measure the home-range size of 1 bellbird (#7). Five of the bellbirds were detected regularly within 60 m of the site where they were captured. The other 2 were always detected at least 100 m away. Two of the 5 regularly detected near their capture location were occasionally detected 400–500 m away, in gullies with flowering flax (*Phormium tenax*) and kowhai (*Sophora microphylla*). The full home range (100% MCP) of bellbird #7 was at least 3.7 ha, and its core home range (90% MCP) was at least 0.2 ha. Its night-time roost was near the centre of its home range. First departure from the roost was before sunrise and last arrival about sunset. If used more extensively, radio telemetry would be useful for measuring home ranges and detecting long-range movements of bellbirds.

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Keywords *Anthornis melanura*; bellbird; home ranges; movements; radio telemetry

INTRODUCTION

Understanding space use is critical for understanding aspects of the behavioural ecology of a species, including habitat selection, foraging behaviour, and the spacing and interactions between individuals or pairs (Harris *et al*. 1990; Laver & Kelly 2008; Anich *et al*. 2009). Measures of space use include population density, home range, and territory. Density is usually expressed as the number of individuals or pairs per hectare (ha), but from this can be calculated the average unit of area (ha or m^2) available per individual or pair. Home range is the area actually used by an individual or pair for normal activities such as feeding and breeding, which may be smaller or larger than the average area available. Territory is the area defended by an individual or pair for exclusive use, usually for breeding, and is usually smaller than the home range (Anich *et al*. 2009). Home range is the most useful measure of space use because it encompasses all the area an individual or pair needs to survive.

Home-range and territory size of the bellbird (*Anthornis melanura*), a forest-dwelling honeyeater (Passeriformes; Meliphagidae) endemic to New Zealand, have been estimated previously by plotting the locations of resighted colour-banded birds (Sagar 1985; Anderson & Craig 2003). Strictly, territory size should be determined by plotting the locations of boundary conflicts between neighbouring

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Table 1. Male bellbirds that we fitted or attempted to fit with radio transmitters, Kennedy's Bush (KB) and Cass Peak (CP) Reserve, 2004.

Bird #	Date of capture	Forest/ net site	Leg-band combination	Body mass (g)	Attachment weight (%)[2]	Date of last signal	Date of first no signal	Days of signal transmission
1	22 Oct	KB/1	R/R –/M	33.8	4.5[3]	-	-	-
2	22 Oct	KB/1	Y/Y –/M	34.0	4.5[3]	-	-	-
3	27 Oct	KB/1	–/– Y/R	34.0	3.7[3]	-	-	-
4	27 Oct	KB/1	–/– W/Y	32.0	3.9	15 Dec	17 Dec	49–50
5	28 Oct	KB/2	Y/G R/M	38.0[1]	4.2[3]	-	-	-
6	28 Oct	KB/2	–/– W/R	34.5	3.6	10 Dec	12 Dec	43–44
7	28 Oct	KB/2	R/M R/Y	33.1[1]	4.8	10 Dec	12 Dec	43–44
8	28 Oct	KB/2	–/– Y/W	34.2	3.7	17 Dec	18 Dec	50
9	28 Oct	KB/3	–/– R/–	34.0	3.5	10 Dec	12 Dec	43–44
10	01 Nov	CP/4	–/– W/M	35.3	3.5	17 Dec	20 Dec	46–48
11	01 Nov	CP/5	Y/– R/M	33.7[1]	4.5	20 Dec	21 Dec	49

[1]Recapture weight minus estimated weight of bands. [2]Transmitter and leg-bands as % of body weight. [3]Transmitter not attached successfully or fell off.

individuals or pairs and/or the locations of singing birds (Anich *et al.* 2009). Furthermore, plotting the locations of colour-banded birds may underestimate home-range size because birds may be difficult to find in the extremities of their range (Anich *et al.* 2009). Radio telemetry has been used with success to determine the home ranges of many species (Harris *et al.* 1990; Laver & Kelly 2008; Anich *et al.* 2009), but has not been used previously to measure bellbird home range. Here we report a small feasibility study to determine the usefulness of radio telemetry for this purpose.

METHODS

Study areas

The study was undertaken in Kennedy's Bush (86.5 ha; 43° 63′S, 172° 62′E) and Cass Peak Reserve (4.4 ha; 43° 64′S, 172° 62′E), Port Hills, Christchurch. Both were regrowth remnants of mixed hardwood forest, containing a range of species including kanuka (*Kunzea ericoides*), fuchsia (*Fuchsia excorticata*), mahoe (*Melicytus ramiflorus*), lemonwood (*Pittosporum eugenoides*), five-finger (*Pseudopanax arboreus*), karamu (*Coprosma lucida* and *C. robusta*), and kowhai (*Sophora microphylla*). There were also a few podocarps, including matai (*Prumnopitys taxifolia*), kahikatea (*Dacrycarpus dacrydoides*), and totara (*Podocarpus totara*). Flax (*Phormium tenax*) grew around the edges of the forests.

Capture and radio-transmitter attachment

Mist nets (2.7 m high × 12.2 m long, with 3.8 cm mesh) were erected at 5 locations (at least 100 m apart) on tracks in Kennedy's Bush and 2 locations 100 m apart in Cass Peak Reserve, between 22 Oct and 1 Nov 2004. Bellbird song (external and local dialects) was played from 2 speakers alternately, 1 each side of the net, to lure bellbirds into the net. Nine adult males were caught in Kennedy's Bush and 2 adult males in Cass Peak Reserve (Table 1). Three of the birds (#5, 7, and 11) were recaptures from previous studies. One female bellbird was also caught in Kennedy's Bush, but we attached transmitters only to the males because of concerns that females, which do all the incubation (Heather & Robertson 1996), may abandon the nest if disturbed at this time of year.

Captured males were weighed to the nearest 0.5 g using Pesola scales, banded with size C metal and/or plastic colour-bands, and equipped with a BD-2 radio transmitter (Holohil, Carp, Ontario, Canada). The transmitters had a pulse rate of 20 pulses per min (each pulse 20 ms), and the manufacturers claimed a battery life of 56 days. We attached the transmitters to the backs of each bird using a modified figure-of-eight harness (after Doerr & Doerr 2002). In the only previous radio-telemetry study of bellbirds, to determine survival and dispersal of birds following translocation, transmitters were glued onto the back or tail feathers (Empson 2003; R. Empson, *pers. comm.*). However, we followed Woolnough *et al.* (2004) who recommended harness attachment of transmitters rather than glueing for medium-sized (20–100 g) passerines. The harnesses we used were made of 0.4 mm diameter synthetic Coated Vicryl™

(Polyglactin 910; Ethicon, USA), normally used as a veterinary suture. This material dissolves slowly on exposure to moisture, but was expected to last at least 3 months, depending on environmental conditions (Doerr & Doerr 2002).

We had difficulty using adjustable harness loops as recommended by Doerr & Doerr (2002) and could not get the harness and its attached transmitter package to stay on the first 2 bellbirds captured, so switched to using traditional fixed-size loops (Rappole & Tipton 1991). We practised putting harnesses of different sizes onto a dead greenfinch (*Carduelis chloris*), similar in size and weight to bellbirds, and from this we determined the appropriate loop size (24–25 mm). We thought the transmitter was correctly attached to the 3rd bellbird we caught, but 3 days later found the transmitter on the ground, 50 m from where it had been attached to the bird. The transmitter remained on the 4th bellbird, but fell off the 5th bellbird within about 5 min (see below). The transmitters remained on all 6 remaining bellbirds for at least the life of the battery (Table 1). The probable reason why the 2 transmitters fell off was that we did not get the harness loops sufficiently over the tibiotarsal joints. Once we had mastered the technique, it took about 5 min to extract a bird from the mist net, weigh it and attach the transmitter package. The transmitter batteries lasted about 46 days, 10 days shorter than the claim of the manufacturers (Table 1).

The average weight of the captured male bellbirds (n = 11) was 34.2 ± 0.5 g (± SE_{mean}). The transmitter package (1.08 g), harness (0.07 g), metal leg-band (0.28 g), and up to 3 coloured-plastic leg-bands (each 0.05 g) together weighed a maximum of 1.59 g. Metal bands and the full compliment of coloured plastic bands were not put on all birds, so the weight of attachments (transmitter package and leg-bands) ranged from 3.5 to 4.8% of the bird's body weights (Table 1). This is within the accepted limit of 5% for the weight of back-mounted devices relative to the body weight of birds (Kenward 2001).

Re-location of birds

We made 26 visits to the study areas between 22 Oct and 27 Dec 2004. Colour-banded birds were resighted incidentally during the course of other work but we did not search for them systematically.

A hand-held radio receiver (TR4, Telonics, Mesa, Arizona, USA) with a Yagi aerial (Sirtrack, Havelock North, New Zealand) was used at 1–4 day intervals to determine the direction of each bird from 1 or more of 3 vantage points inside the forest and 4 vantage points outside the forest. From these records we determined whether the birds were still in the vicinity of where they were captured. The receiver could detect transmitters at least 500 m away, even through forest. When the Yagi aerial was removed from the receiver the detection distance was reduced to about 15 m, at full gain. We used the receiver without the aerial only to check if birds were still near the site where they were caught or to verify partial colour-band sightings. We did not search extensively for birds using this method.

Four purpose-built "proximity sensors" (modified from Ball *et al*. 2005) were used in an attempt to determine the home range of 1 bellbird (#7). Each sensor consisted of a Regal 1000 VHF tracking receiver (Titley, Brisbane, Australia) connected to a 500 mm vertical whip aerial standing on the ground and a purpose-built data logger, powered by a 12 V battery. At a gain setting of 4 the receivers could detect transmitters up to about 15 m away, which was above canopy height (*c*. 10 m). We established a 330 × 330 m plot around the net site where bellbirds #5, 6, 7, and 8 were captured, and gridded this at 30-m intervals, on the assumption that there would be no overlap in detection of the birds from adjacent grid locations. Initially we scanned simultaneously for birds #6, 7, and 8 (#5 having lost its transmitter), but did not detect #6 or 8, and so most scanning was for #7 only. The proximity sensors operated 24 h per day, and were shifted systematically to different locations on the grid at 1–4 day intervals from 19 Nov until bellbird #7's transmitter battery went flat (10 Dec). Only 21 of the 121 locations on the grid were monitored in this time, though some locations outside the grid were also monitored.

The data loggers recorded the arrival and departure times, to the nearest minute, each time the transmitter signal from bellbird #7 was within receiving distance of the proximity sensors. From these records we calculated the percentage of time that the bird was detected at each sensor location, from the total time it was detected there divided by the total time that the sensor was operating.

We used an area-of-polygon calculator (http://www.analyzemath.com/Geometry_calculators/irregular_polygon_area.html) to estimate the full home range of bellbird #7, by connecting all locations where it was detected to create a minimum convex polygon (100% MCP). We also connected the locations where it was detected more often than would be expected from an equal-use pattern (Samuel *et al*. 1985) to estimate its core home range. These estimates should be considered minimums because we did not monitor all possible locations bellbird #7 could have visited.

RESULTS

Resighting records

Immediately after release, 3 bellbirds flew to branches in nearby trees (whereas the others flew out of sight), and we observed their initial reactions

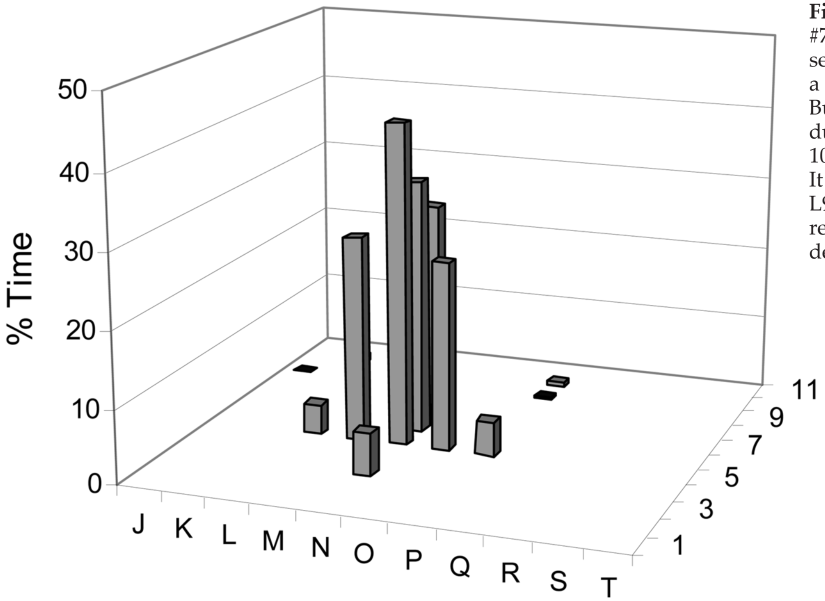


Fig. 1. Percentage of time bellbird #7 was detected by proximity sensors at various locations on a 330 × 330 m grid in Kennedy's Bush (grid locations 30 m apart), during the daytime, 19 Nov to 10 Dec 2004 (K10, 0.9%, obscured). It was not detected at J5, J7, J10, L9, L10, N9, N10, or R9. The remaining grid locations with no detections were not monitored.

to the leg-bands and transmitter packages. Bellbird #3 pecked at its new leg-bands (but not at the transmitter package) on and off for 5 min, and then started feeding (gleaning on kanuka) for another 15 min before flying out of sight. Bellbird #5, a bird that had been banded previously, pecked at the transmitter package on its back, shook its body, flapped its wings and performed vigorous acrobatics among the branches of a tree for about 5 min, until the transmitter package slipped off. Bellbird #11, also banded previously, sat quietly on a branch for about 2 min and then preened its back feathers for about 3 min, before flying away.

During the course of other work we resighted 7 of the 11 banded bellbirds a total of 29 times (bellbird #7 was resighted 15 times, #9 five times, #4 four times, #11 twice, and #3, 5, and 10 once each). Five of the bellbirds (#4, 7, 9, 10, and 11) had transmitters on. All birds appeared to behave normally (feeding, singing, and flying). Bellbirds #7, 9, and 11 were seen chasing other male bellbirds away from near where they were captured – evidence of territorial behaviour.

All except 6 of the 29 resightings were within 60 m of the birds' capture sites. Bellbird #4 was seen once near its capture site, once 130 m away, once 240 m away, and once 250 m away. The distant sightings were on the edges of an open gully leading to a large patch of flowering flax at the top, about 500 m from bellbird #4's capture site. When it was seen at 130 m, it had flax pollen (identified by colour) on its head. Bellbird #7 was resighted 12 times within 60 m of its capture site, once 70 m away, once 100 m away, and once 120 m away. The most distant sighting (120 m) was in a small clump of flowering flax. We also saw an unbanded bellbird with flax pollen on its head, more than 200 m from the nearest flowering flax.

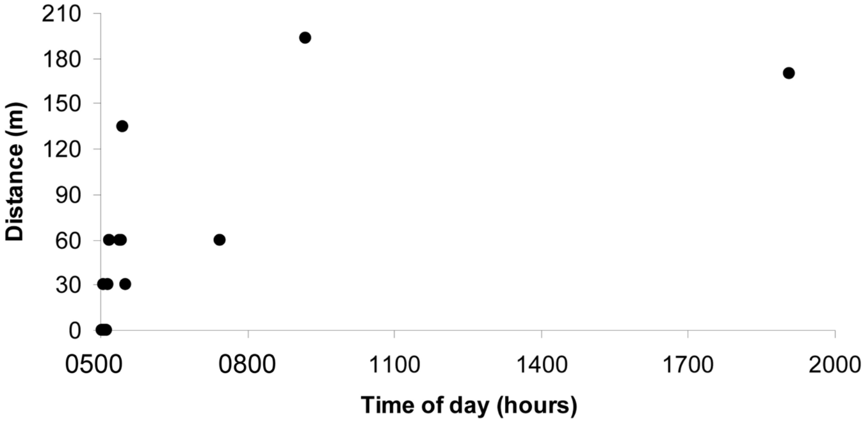
Of the 4 bellbirds captured at net site 1, only #3 and 4 were resighted there, once each. Of the 4 bellbirds captured at net site 2, #7 was resighted there 12 times and #5 once. The other bellbirds captured at these sites were not seen there again.

Radio-receiver records

All 7 bellbirds with radio transmitters were detected on the radio receiver with the aerial attached, from vantage points inside and outside the forest, on all days they were searched for, until the transmitter batteries went flat. By triangulation of these records, we found 4 of the 7 bellbirds (#4, 7, 9, and 11) were always in the general vicinity of their capture site. Two others (#6 and 8) were always at least 100 m away from their capture site. These 2 birds were caught at the same site as bellbird #7, but perhaps were at the edge of their home range when caught, lured to the net by song playback. Bellbird #10 was sometimes detected at its capture site in Cass Peak Reserve, but was also detected in Kennedy's Bush, more than 500 m away, in a gully where kowhai was flowering. On 3 occasions it was detected in Cass Peak Reserve in the morning and in Kennedy's Bush in the afternoon.

All the radio-marked bellbirds, except #6 and 8, were detected on the radio receiver with the aerial removed (detection distance 15 m), usually within 60 m of the net site where they were captured. However, bellbird #4 was detected 4 times at

Fig. 2. Time of day bellbird #7 was first detected at various distances from its night-time roost, Kennedy's Bush, 22 Nov to 1 Dec 2004.



distances up to 400 m from its capture site. All 4 detections were in a gully leading up to a large patch of flowering flax. On 1 of these occasions it was also seen, and it had flax pollen on its head (see above).

Proximity-sensor records

Bellbird #7 was detected by the proximity sensors at 12 of the 21 grid locations that were monitored (Fig. 1). During the daytime, it was detected at N5 about 43% of the time that a sensor was located there. It was detected at other locations around N5 less frequently. The equipment malfunctioned at N4, so no records were obtained for that location. However, we saw the bird at N4 and it appeared to spend less time there than at N6. It was not detected by the proximity sensors at 8 of the 21 grid locations on the days that they were monitored (Fig. 1) but if visits were infrequent it may have visited those locations on days when they were not monitored. For example, it was detected with the hand-held receiver once at N10, and was seen once between N7 and N8, once between J5 and K5, and once at M1. The percentage detection at different locations added up to more than 100%, indicating that there was some overlap in detection between proximity sensors at adjacent locations on the monitoring grid.

The full home range (100% MCP) of bellbird #7, including the 12 locations where it was detected with the proximity sensors and 4 additional locations where it was seen and/or detected with the hand-held receiver, was at least 3.7 ha. If we exclude outlying locations where it was detected less than 1% of the time, its home range was at least 0.7 ha (99% MCP). If we include only locations where it was detected more often than would be expected from an equal-use pattern, its home range (which we defined as its core home range) was at least 0.2 ha. It was detected there 90% of the time, so this is equivalent to its 90% MCP home range.

At night, bellbird #7 was detected by the proximity sensors only at N5. This was where it was detected most often during the day, and was near the centre of its home range. We found an old nest near N5 but did not find one still in use (although we did not search extensively).

Bellbird #7's first detected movement of the day was departure from N5 (its night-time roost), between 0503 and 0512 h (NZ Summer Time) on the 4 days it was monitored there (Fig. 2). Its first detected movement at neighbouring locations was always arrival, and times were always later than its departure time from N5 on the same day. First arrival times at the more distant locations in its home range were sometimes quite late in the day (e.g. P10 was not visited until 1907 h one day), and some locations (e.g. J9, P9, and P10) were not visited at all on some days. Bellbird #7's last detected movement of the day was arrival at N5, between 2044 and 2100 h on the 4 days it was monitored there (Fig. 3). Its last detected movement at neighbouring locations was always departure, and times were always earlier than its last arrival on the same day at N5. Last departure times from the distant locations in its home range, as with first arrival times, were quite variable and sometimes in the morning (e.g. on 1 day the last departure from J9 was at 0953 h).

DISCUSSION

Our small feasibility study demonstrated that radio telemetry could be used successfully to determine the home ranges and movements of bellbirds. Using a hand-held radio receiver without an antenna we detected radio-marked birds within a 15-m radius, enabling us to plot their locations on a map. It was not always possible to identify these birds from coloured leg-bands because the birds either did not stay within view long enough or the bands were obscured by dense vegetation. However, by walking through a study area with a hand-held

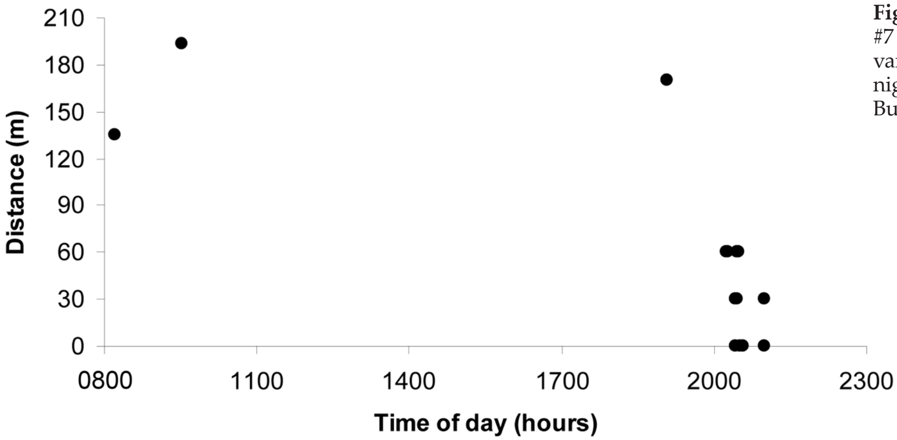


Fig. 3. Time of day bellbird #7 was last detected at various distances from its night-time roost, Kennedy's Bush,

receiver scanning for radio-marked birds it should be possible for an observer to plot all the locations where birds were detected, and to construct home ranges. We did not do this, but instead trialled remote continuously-operating proximity sensors (radio receivers connected to data loggers), systematically moved around a network of locations in the study area to record the locations of radio-marked birds throughout the day and night, without the influence of an observer possibly affecting the behaviour of the birds.

Using a combination of proximity-sensor, radio-receiver, and resighting records we were able to estimate an approximate breeding-season home range for 1 bellbird (#7). Incidental radio-receiver and resighting records of other bellbirds suggest that the size of bellbird #7's home range was reasonably typical, although it may have been smaller than some (e.g. bellbirds #4 and 10). The proximity-sensor records also enabled us to calculate a core area of concentrated use within the home range (after Samuel *et al*. 1985). We do not know if all of the core home range, as we defined it, was defended against other bellbirds, and therefore cannot say it was the same as the territory. More extensive use of proximity sensors in future studies would enable a better estimation of bellbird home ranges.

The proximity-sensor records enabled us to identify the night-time roost of bellbird #7 and the times of its morning departure and evening arrival. The roost (and an old nest site) was near the centre of its home range. The home ranges of bellbirds on Tiritiri Matangi I were also centred round the nest site (Anderson & Craig 2003). Recorded departure times of bellbird #7 (0503–0512 h) were about 30–40 min before sunrise, which was about 0545 h (http://www.timeanddate.com/worldclock/astronomy.html?n=951). Interestingly, bellbirds near Akaroa, 40 km to the east, started singing about 40–45 min before sunrise at the time of our study (J. Chetwynd, *pers. comm.*). Bellbird #7's last recorded arrival times at its night-time roost were around sunset, which was about 2045 h.

The home-range size of bellbirds has been estimated previously only once, on Tiritiri Matangi I, from observation of colour-banded birds (Anderson & Craig 2003). In that study, the average area over which pairs ranged during the breeding season was only 0.02 ha, and the core range (defined by Anderson & Craig 2003 as where both members of a pair were typically found throughout the day) was only 0.014 ha. These areas are much smaller than the home range of bellbird #7 and likely other bellbirds in our study areas. This could be attributable to 2 factors: habitat quality and the method used to detect birds. Tiritiri Matangi I probably had better habitat for bellbirds than Kennedy's Bush and Cass Peak Reserve; e.g. it had more nectar-bearing food sources for bellbirds, such as rewarewa (*Knightia excelsa*) and pohutukawa (*Metrosideros excelsa*), in addition to flax (Anderson & Craig 2003). Thus, birds probably did not need to forage over such large distances as they did in our study areas, where the main nectar sources were kowhai and flax, which occurred mainly in gullies and around the edge of the forest. In the USA, Anich *et al*. (2009) noted that the home-range sizes of Swainson's warbler (*Limnothlypis swainsonii*) tended to be smaller in higher-quality habitats than in poorer-quality habitats. Tiritiri Matangi I also had no brushtail possums (*Trichosurus vulpecula*), stoats (*Mustela erminea*), or ship rats (*Rattus rattus*) (Anderson & Craig 2003), known bellbird competitors and/or predators, which were present in Kennedy's Bush and Cass Peak Reserve. These could have contributed to lower bellbird density (and larger bellbird home ranges) in our study areas. On Tiritiri Matangi I, Anderson & Craig (2003) relied on resighting colour-banded birds whereas we used radio telemetry, which allowed us to detect birds where they might not have been seen or heard. Anich *et al.* (2009) reported that home-range sizes of Swainson's warbler estimated from radio-telemetry records were much larger than those estimated from territory mapping and resighting of colour-banded birds. This factor is probably more important at lower density, as in our study areas, than at higher density, where birds are closer together, as on Tiritiri Matangi I.

We did not estimate the territory size of bellbirds in our study areas, and we are not aware that bellbird territory size has been estimated in any previous studies. However, Sagar (1985) reported that up to 11 pairs of colour-banded bellbirds defended territories in a 0.45-ha study area on Aorangi Island, Poor Knights Is, giving a potential average territory size of 0.04 ha. Subsequently, from a capture–recapture study, Sagar & Scofield (2006) estimated there were 5.5–9.1 breeding pairs per hectare on Aorangi I, giving a potential average territory size of 0.11–0.18 ha. Home-range sizes were not estimated, but would have been larger than territory sizes because birds were reported to travel to seasonal food sources and a freshwater pool outside their territories (Sagar 1985). Based on the above, it is likely that the home-range sizes of bellbirds on Aorangi I, as on Tiritiri Matangi I, would have been much smaller than in our study. This is most likely related to habitat quality, as noted above.

We estimated the number of pairs of bellbirds per hectare in our study areas in Nov 2004 from counts of the number of bellbirds (mainly singing males) in 1-ha plots, as part of another study (Appendix 1). The average area available per pair calculated from these density estimates was 0.8–0.9 ha, similar to bellbird #7's 99% MCP home range (minimum 0.7 ha), measured using the proximity sensors. Other researchers have also estimated the number of bellbird pairs per hectare, mostly from territory mapping or counts of the number of pairs in a known area of forest, in other parts of the country (Appendix 1). The average area available per bellbird pair in these studies ranged from 0.04 to 3.7 ha in different habitats. Home-range sizes may have been larger or smaller than these values, depending on whether all the available area was used by bellbirds and whether home ranges overlapped. On Tiritiri Matangi I, the average area used by bellbird pairs (0.02 ha) was much smaller than the area available per pair (0.5 ha) (Anderson & Craig 2003), implying that the area used was underestimated (see above) and/or not all the available area was utilised. Despite this, home-range overlap was reported (Anderson & Craig 2003), as in our study.

We found that bellbirds will fly at least 500 m from their core home range to patchy, seasonal, food sources such as nectar from kowhai and flax. We probably would not have detected these long-range movements without radio telemetry. Previous studies have also noted that bellbirds may leave their territory for short periods to visit localised seasonal food sources (Gravatt 1970; Craig *et al*. 1981; Sagar 1985; Anderson & Craig 2003), but the distances travelled were not stated. The willingness of birds to use such food sources may result in home ranges that vary considerably at different times of the year, as the availability and distribution of these resources changes, as also noted by Harris *et al*. (1990). In addition, there is evidence that bellbirds undertake seasonal altitudinal movements of several kilometres from forest patches on the Port Hills, such as Kennedy's Bush, Cass Peak Reserve, and Victoria Park, to lower-altitude gardens and parks in Christchurch city in winter. For example, our bellbird #11, which held a territory in Cass Peak Reserve in Nov 2004, was originally banded (with metal band number C-58007) in the lower Lansdowne Valley, at the foot of the Port Hills, 4 km away, in Jun 1997 (Spurr *et al*. 2008). Also, 2 adult male bellbirds banded on breeding territories in Victoria Park in Jan 2002 were seen in gardens in lower Cashmere, also at the foot of the Port Hills, about 2 km away, 1 in Jun 2002 and the other in May 2004 (Landcare Research, *unpubl. data*). These examples of purported seasonal movements were obtained from opportunistic sightings of banded birds. More comprehensive information on seasonal movements could be obtained by attaching radio transmitters to birds.

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Appendix 1. Bellbird density during the breeding season reported in various studies, from which we calculated the average area available per bellbird pair.

Study	Location	Habitat	Area (ha)	Pairs /ha	Area/pair (ha)
Kikkawa (1966)	Various South I	Beech	40	0.3	3.7
Kikkawa (1966)	Various South I	Podocarp	40	0.6	1.8
Kikkawa (1960)	Kapiti I	Hardwood	3.4	0.9	1.1
Kikkawa (1964)	Little Barrier I	Hardwood	14.2	1.0	1.0
Authors (*unpubl. data*)	Kennedy's Bush	Hardwood	86.5	1.1	0.9
Authors (*unpubl. data*)	Cass Peak Reserve	Hardwood	4.4	1.3	0.8
Kikkawa (1966)	Various South I	Hardwood	40	1.2	0.8
Anderson & Craig (2003)	Tiritiri Matangi I	Hardwood	4	2.1	0.5
Turbott & Bull (1954)	Great I	Kanuka	4	2.8	0.4
Sagar & Scofield (2006)	Aorangi I	Hardwood	66	5.5–9.1	0.11–0.18
Sagar (1985)	Aorangi I	Hardwood	0.45	24.4	0.04