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Home range sharing in family units of great spotted kiwi (*Apteryx haastii*) at Nelson Lakes National Park

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Abstract Home range size and overlap in adult (> 4.5 years) and subadult (< 4.5 years) great spotted kiwi (*Apteryx haastii*) was investigated using telemetry at the Rotoiti Nature Recovery Project, Nelson Lakes National Park, in 2012. The population had been introduced between 2004 and 2006. The mean home range size of adults was 34.4 ha (± 9.4 SEM) and 17.4 ha (± 5.7 SEM) for subadults. Overlap between subadult and adult home ranges ranged from 78-99% and subadults were located roosting within 50 m of a parent on at least 50% of observations. Several subadults, aged more than 4 years, have also been located sharing burrows with adults. These observations suggest great spotted kiwi are similar to southern tokoeka (*A. australis*) in that they have substantially more parental association with their offspring than the better known North Island brown kiwi (*A. mantelli*).

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INTRODUCTION

The great spotted kiwi (*Apteryx haastii*) or roroa/roa, is endemic to the South Island and is the least known of all kiwi species (Van Hal 2007; Wilson 2004). Its population and range has decreased since human settlement although its historical range was probably always confined to the north-western part of the South Island (McLennan 1990). The species is now restricted to 3 main isolated populations: Kahurangi National Park, the Paparoa Range, and the Arthur's Pass–Hurunui region (McLennan & McCann 2002). Notable genetic differences between these populations exist due to limited gene flow caused by low levels of dispersal (Baker *et al.* 1995). The total great spotted kiwi population was estimated at 22,000 individuals (McLennan & McCann 2002), but more recent estimates suggest only 16,000 birds, and a further decrease to 13,000 birds is projected by 2018 (Holzapfel *et al.* 2008). The main agent of decline is predation of chicks and juveniles by stoats (McLennan & McCann 2002), which results in recruitment failure and the gradual population decline (Hitchmough *et al.* 2007). Great spotted kiwi are classified as 'nationally vulnerable' (Miskelly *et al.* 2008).

Little was known about great spotted kiwi before a 4-year study at the southern Gouland

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Downs, Northwest Nelson, by McLennan and McCann (1991). Subsequently, the ecology, genetics, and distribution of the species were summarised by McLennan and McCann (2002), and its behaviour and population characteristics were described by Robertson *et al.* (2005). Keye *et al.* (2011) recently studied summer home range and movements. Great spotted kiwi inhabit mostly mountainous beech (*Nothofagus* spp.) and podocarp (Podocarpaceae) forests, but also extend their feeding range onto valley floors covered by tussock grassland (McLennan & McCann 2002; McLennan & McCann 1991). They are the largest of the kiwi with adult males weighing 1.75–3 kg and the larger females at 2.3–4.3 kg. Females lay 1 egg from mid-winter to mid-summer, and both male and female incubate the egg (McLennan & McCann 1991). The mean life expectancy of kiwi in the Gouland Downs was estimated at 25 years (Robertson *et al.* 2005).

Adult great spotted kiwi are territorial and defend their territories in pairs or individually (Keye *et al.* 2011; Robertson *et al.* 2005). Keye *et al.* (2011) found that the home ranges of paired individuals within a particular territory overlapped extensively but were not identical. Great spotted kiwi form long-lasting monogamous pair bonds (Robertson *et al.* 2005), but surplus females may cause a divorce and creation of new pair bonds (Keye 2008; Taborsky & Taborsky 1999). Territories of great spotted kiwis may stay unchanged for many years. For example, 2/11 territories in the Gouland Downs were occupied by the same individual, although not always with the same partner, for 17 years. One territory was occupied by the same pair for at least 12 years (Robertson *et al.* 2005). It is not known when or how far the offspring disperse from their natal territories (Burbidge *et al.* 2003; Robertson & Colbourne 2003).

Studies on great spotted kiwi behaviour and population characteristics, such as home range, have been conducted on naturally occurring populations in Kahurangi National Park (McLennan & McCann 1991; Robertson *et al.* 2005), or the Arthur's Pass–Hurunui district (Keye *et al.* 2011). However, home range of translocated great spotted kiwi populations may be different, given that structure of kiwi territories in natural populations evolves gradually (McLennan *et al.* 1987; Robertson *et al.* 2005). The aims of this study were to determine how adult great spotted kiwi and their offspring associated spatially and to investigate when subadults leave their natal home ranges.

METHODS

Study area

The research was carried out in the Rotoiti Nature Recovery Project (RNRP), a 'mainland island' established within Nelson Lakes National Park in 1996; the 'mainland island' now encompasses some 5000 ha (Harper *et al.* 2011). The study area extended from the eastern shore of Lake Rotoiti (620 m a.s.l.) to the main ridge of the St Arnaud Range (1670–1787 m a.s.l.). Most of the study site is clothed in well-drained climax forest on mainly steep mountain sides, dominated by red beech (*Nothofagus fusca*), silver beech (*N. menziesii*) and black beech (*N. solandri* var. *solandri*), with mountain beech (*N. solandri* var. *cliffortioides*) in the higher altitudes, up to the abrupt tree line at 1400 m a.s.l. On gentle colluvial slopes close to the lake, wet patches of mixed forest occur, which are dominated by kanuka (*Kunzea ericoides*) and manuka (*Leptospermum scoparium*). The alpine zone is covered by tussock grasslands or is formed by scree fields. The mean annual rainfall at Lake Rotoiti is 1560 mm and at lake level snow can fall at any time of the year and will often remain for days or weeks over the winter and early spring.

Great spotted kiwi population

Sixteen great spotted kiwi were translocated to the RNRP from Gouland Downs between 2004 and 2006 (Paton *et al.* 2007), and since then at least 9 chicks have fledged. In addition, 5 Operation Nest Egg juvenile kiwi have recently been introduced. With known deaths, the current population stands at ~25 birds.

The study was carried out between May and Aug 2012. The birds were divided into age classes according to Robertson and Colbourne (2003): chick (0 to 10–50 days), juvenile (50 days to 6 months), subadult (6 months to 4.5 years), and adult (over 4.5 years.

Radio tracking and error estimation

Previously radio-tagged kiwi were located using telemetry during the study. The birds carried leg-mount kiwi transmitters (Sirtrack or Kiwi Track). Juveniles and subadults of less than 1000 g carried smaller and lighter transmitters with short external antennas (Miles & McLennan 1998). TR4 receivers (Telonics™) and 3-element folding yagi aerials (Sirtrack Ltd) were used to locate birds. The bearing of the signal direction was recorded and the triangulation point coordinates were obtained by GPS (Garmin Oregon 400t). The same procedure was repeated several times from different locations to increase the triangulation accuracy. Usually 3 to 5 bearings were taken using a mirror compass (Suunto MC-2 Global) from various angles to obtain the recommended minimum overall angle of 90° (Kenward 2001). This allows triangulation of a kiwi location with a reasonable degree of confidence (Neill & Jansen 2010).

To assess location error, a beacon test was conducted (Millspaugh & Marzluff 2001). Two radio-transmitters were placed at known locations in the study area and their location was repeatedly determined in the same manner as the radio-tagged

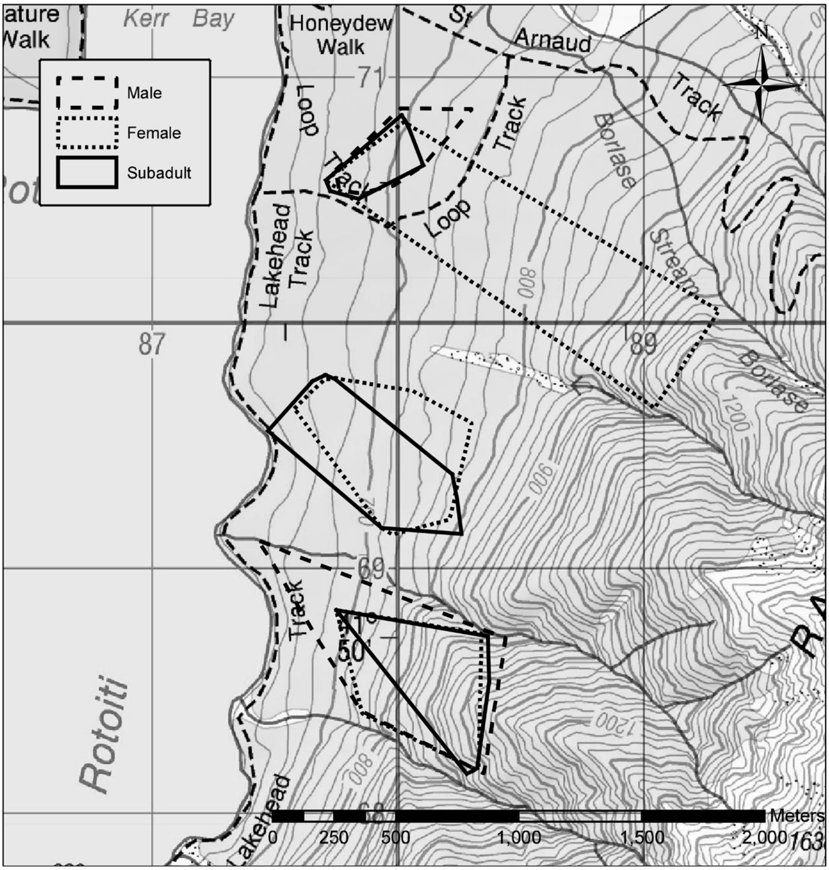

Fig. 1. Minimum Convex Polygon (MCP) home ranges of adult and sub-adult great spotted kiwi at the Rotoiti Nature Recovery Project, during the winter of 2012 (© Crown Copyright, LINZ).

birds. One transmitter was placed on a gentle slope and the other on a steep spur in order to reflect differences in topography. Location error was calculated as the mean distance between the actual and estimated locations of the test transmitters. Precision, as a measure of consistency of radio-tracking, was expressed by 95% confidence ellipses around the estimated bird locations. Confidence ellipses were computed by the triangulation software Locate 3.34.

Birds were located once a day during the daytime to reduce autocorrelation and obtain independent observations (Laver & Kelly 2008), as kiwi tend to use different shelters every day, but do not change them once they have chosen a roost for the day (McLennan *et al.,* 1987). The decision to collect daytime location points only was based on the observation of Keye (2008), who found that daytime location fixes were sufficient for delineating great spotted kiwi home range, and by feasibility and safety constraints of data collection. Kiwi were located on a random basis in order to obtain a sufficient number of location fixes per each bird. However, an effort was made to find all family members in one day to establish their spatial interactions. The number of birds located per day depended on the time required to find each particular bird in field. Most of the time, it was possible to find and triangulate 3 to 5 birds a day. Field work was weather-dependent as data collection was not possible for several days after heavy snow falls or during heavy rain.

Interactions of subadults and their adult parents were assessed by the analysis of distances between roosting sites of subadults and adults, and by the analysis of home range overlap between subadults and their parents. Due to the limited accuracy of triangulation, distances between subadults and adults were classified into 3 categories: (1) sharing a roosting site or in close proximity of a subadult and its parent (0–50 m), (2) a subadult's roosting site being within calling distance from a parent (50–500 m) and, (3) roosting at locations of more than 500 m. If a family member could not be located, it was assumed to be located more than 500 m away. For one bird (Subadult 1), only interactions with its mother could be taken into account, as its father could not be found.

Table 1. Identity, sex and age of radio-tagged great spotted kiwi.

Bird	Family	Sex	Age class	Estimated age (yr)
Te Matau	1	M	Adult	11.00
Onekaka	1	F	Adult	≥10.00
Chick 7	1	N/A	Subadult	0.75
Anatoki	2	F	Adult	≥10.00
Subadult 1	2	F	Subadult	3.50
Onahau	3	M	Adult	≥10.00
Tai Tapu	3	F	Adult	11.00
Chick 5	3	N/A	Subadult	2.50

In addition to assessing interactions between birds with telemetry data, observations of birds co-located in burrows since the establishment of the population were analysed for instances in which adults and juveniles were found sharing daytime roosts.

Data analysis

Home range refers only to period Jan – Aug 2012. Most of the home ranges of kiwi were based on locations of birds from late May to Aug 2012 as well as with location points from the recent regular checks by Department of Conservation (DOC) staff earlier in the year. These earlier locations were recorded using GPS (Garmin 60CSx) where a kiwi was found.

Computations of animal locations were performed by the triangulation software Locate 3.34 (www.locateiii.com). Minimum Convex Polygon (MCP) home range estimators were used for analysis. The MCP constructs a home range as a minimum polygon formed by outer location fixes (Walsh *et al.* 2006). Ranges 7 (www.anatrack.com) was used to establish MCP. This software also provides an incremental area analysis, which was crucial for establishing a minimum number of locations required for a robust estimate of a home range (Millspaugh & Marzluff 2001). Seaman *et al.* (1999) suggest that a minimum of 30 location fixes per animal should be reached, and preferably more than 50. However, this is a general rule and applies to daytime activity tracking. Keye (2008) observed that great spotted kiwi roost during the daytime and mostly along the boundaries of their home ranges. Thus, home range based on daytime tracking requires a smaller number of location fixes. It was also noted that their home range area reached an asymptote at ~16 location fixes, suggesting that this number should be sufficient for a home range analysis. Given the trade-off between sampling intensity and sample size in a limited timeframe, the suggestions of Keye (2008) were accepted and the target number of kiwi locations for this study was set at 18. Nevertheless, the adequacy of this sample size was examined through the incremental area analysis once the intended number of location fixes was collected. Additional location fixes were added if an area-observation curve of the given home range had not reached its asymptote at 18 locations. Modified 1:50,000 topographical maps from Land Information New Zealand (LINZ) were used for spatial reference. Statistical *t*-tests and ANOVAs were run in Minitab 16 (www.minitab.com).

RESULTS

Five adult birds and 3 subadults were studied. The 8 birds formed 3 families; 2 pairs and 1 female, along with their respective offspring (Table 1). Before the end of data collection, Subadult 1 dropped its transmitter and therefore its monitoring was ended earlier.

Home range

Mean location error for the 2 test transmitters was 18.4 m (± 2.6 SE, n = 12). The precision of triangulation was expressed by 95% confidence ellipses around estimated bird locations. The median area of a 95% confidence ellipse was 123.4 m^2. Triangulated location fixes from all studied birds were pooled for the calculation of precision.

In most cases, 16 locations were sufficient for establishing a home range. However, the area-observation curve of the 2 smallest home ranges did not reach an asymptote at 21 and 23 location fixes, respectively. These 2 home ranges, formed by clumped location fixes, were gradually expanding with each additional location fix. However, the area increments were small and spatially restricted along the edges of the exiting home ranges. On the other hand, in one case an area-observation curve reached an asymptote at only 7 location fixes. On this basis these 2 home ranges were therefore included in the analysis.

Home range analysis revealed that the 3 kiwi families inhabited 3 distinct areas within the study area. The size of established home ranges was notably different between adults and subadults as well as among all the studied birds (Table 2). The mean size of home range of all the studied birds was 28.0 ha (± 6.7 SE, n = 8). The mean size of adult home range was larger than the mean size of subadult home range, but the difference was not statistically significant (2-sample *t*-test, t = 1.55, df = 5, P = 0.091). Onekaka (one of the adult kiwi) spent approximately 2 weeks of the study in a remote upland area, which increased her home range size substantially (Table 2).

Table 2. Home ranges of adult and juvenile great spotted kiwi in the Rotoiti Nature Recovery Project.

Adult	Family	Home Range (ha)	Locations (n)	Juvenile	Family	Home Range (ha)	Locations (n)	All birds
Te Matau	1	10.11	23	Chick 7	1	6.57	21	-
Onekaka	1	66.29	17	Chick 5	3	19.52	18	-
Anatoki	2	28.90	20	Subadult 1	2	25.98	16	-
Onahau	3	41.46	18	-	-	-	-	-
Tai Tapu	3	25.36	18	-	-	-	-	-
Mean		34.42	19.2			17.36	18.3	28.02
SE		9.40				5.70		6.70

Table 3. Distances between roost sites of juvenile great spotted kiwi and their nearest parent as determined by telemetry.

Subadult	Age (yr)	Family	Median (m)	Mean (m)	SE (m)	Observations (n)
Chick 7	0.75	1	17.2	90.0	29.0	20
Chick 5	2.50	3	23.4	144.4	52.9	18
Subadult 1*	3.50	2	23.9	192.3	79.8	14

*only the mother observed for Subadult 1

It appears likely that 4 extreme location outliers of Onekaka could have been caused by her capture and radio-tagging. Onekaka and Chick 7 were radio-tagged on 12 Jun after being located in a burrow they shared with Onekaka's partner Te Matau. She was subsequently not located in the usual home range over the next 3 days. She was found 4 days later, approximately 1.6 km away and 350 m higher up the spur. She remained in that area for at least 2 weeks until she returned to her usual home range with Te Matau and Chick 7. In contrast, Chick 7 was found 3 days later only 235 m away near to Te Matau. Later, when Onekaka and Chick 7 were disturbed but not handled, Onekaka was not located within a 1 km radius the next day, although Chick 7 was only 115 m away from the burrow. Both birds were then found a week later in their usual home range. Similarly, after being disturbed but not handled, Anatoki and Subadult 1 left their usual home range area. When finally located 5 days later, Anatoki and the sub-adult were nearly 600 m and 1800 m away, respectively. However, during those 5 days heavy snow falls occurred and so it is not known what made them abandon the previous location. They did not return there until the end of the study period. As it was difficult to assess what was natural behaviour and what was induced by disturbance, all location points were included in the analyses.

Overlap in home range and roost locations

Both mean and median distances between the subadult and its closest parent were smallest for the youngest subadult, Chick 7. On the other hand, both mean and median distances from a parent were highest for Subadult 1, the oldest subadult (Table 3).

Subadults were found roosting with their parents, or within 50 m in 50–72% of observations (Table 4). In these occasions a subadult was more often found roosting with the mother than the father. The largest difference was observed in Chick 5, which was found with Tai Tapu (mother) in 61% and with Onahau (father) in 33% of all observations. Two subadults were present with both parents on 29% (Chick 7) and 22% (Chick 5) of all observations. When a 400 m radius was used as a threshold, Chick 7 was never found further than this distance from one of its parents, whereas Chick 5 and Subadult 1 were found within 400 m of one of their parents in 78% and 61% of all observations, respectively.

The analysis of MCP home range overlap showed that Chick 5 had the highest proportion of its home range within the home range of its parents, and Chick 7 had a similarly high proportion, 99.2% and 97.8%, respectively. The home range overlap of Subadult 1 and Anatoki was smaller at 77.9%, but only overlap with one parent could be taken into account as the second parent was not known. All the

Table 4. Spatial association of roost sites of juvenile great spotted kiwi with their parents.

Subadult	Age (yr)	Family	Distance from a parent (%)			With a parent (0-50 m; %)		Observations (n)
			0-50 m	50-500 m	>500 m	Male	Female	
Chick 7	0.75	1	61.9	38.1	0.0	42.9	47.6	21
Chick 5	2.50	3	72.2	5.6	22.2	33.3	61.1	18
Subadult 1	3.50	2	50.0	11.1	38.9	N/A	50.0	18

*only the mother observed for Subadult 1

Table 5. Duration of time juvenile great spotted kiwi were co-located with their parents at the Rotoiti Nature Recovery Project.

Subadult	Estimated hatch date	Date last located with parent(s)	Elapsed time
Miharo	1 Feb 2005	8 Aug 2009	4 years 6 months
Rito	1 Feb 2006	24 Apr 2007	1 year 3 months
Ngahere	19 Jan 2007	18 Feb 2011	4 years 1 month
Marama	11 Feb 2008	5 May 2009	1 year 3 months
Chick 5	6 Apr 2010	10 Aug 2012	2 years 4 months

known wild chicks hatched within the RNRP were found with their parents or within the home range of their parents at least a year after hatching (Table 5). Juvenile home range increased as they matured; from 6.6 ha at 0.75 years old to 26 ha at 3.5 years old (Table 2).

DISCUSSION

Home range size

Incremental area analyses showed that 16 location points were sufficient to establish home ranges of at least 5/8 kiwi. Subadult 1 dropped its transmitter after only 16 location fixes and thus it was not possible to assess whether this was sufficient. Te Matau and Chick 7 had the 2 smallest home ranges, but their area-observation curves had not reached their asymptote despite having the highest number of location fixes. Even though further data was not collected, it is not likely their home range would have been substantially larger, given the high location fidelity and relatively small median travel distances between the roosting sites. For that reason, results of all birds were reported, though it is possible the ranges of some birds were under-estimated.

The comparison of observed home ranges or territories of great spotted kiwi in other populations suggests that home ranges of adults at the RNRP are slightly larger than at other areas (Table 6). Only Keye *et al.* (2011) provide full results of great spotted kiwi home range based on the MCP estimator. There was no significant difference between the mean values of adult home range size in the RNRP and in the North Branch of Hurunui Valley (2-sample t-test, $t = -0.19$, $df = 4$, $P = 0.86$). Home range sizes in the RNRP were also similar to those of the source population in the Gouland Downs, which suggests the translocation did not affect home range size. This similarity would likely be closer if Onekaka's large home range (Table 2), likely caused by disturbance, was not included. In order to avoid possible disturbance bias in future, study birds should have no human contact during the research period and suggested settling period would be at least 2 weeks long.

The home ranges of the studied birds were established in 3 separate locations with a high home range overlap within families, but no overlap between birds from different families, which confirms the high degree of territoriality observed in the previous studies (Keye *et al.* 2011; McLennan & McCann 1991; Robertson *et al.* 2005). Given that home ranges of the birds from different families did not share a common boundary, it is difficult to establish the exact boundaries of the family territories. From the results it is not clear if the adults defended only their home ranges as their territories, as suggested by McLennan *et al.* (1987), or if their territories were larger and delineated by the reach of kiwi calls (Colbourne & Kleinpaste 1984). Wylie and Nelson (2010) suggest that size and shape of great spotted kiwi territories vary between regions and populations depending on geography. In the rolling landscapes of Gouland Downs for example,

Table 6. Comparisons of home range sizes of adult great spotted kiwi.

Locality	Home range (ha)			Reference
	Range	Mean	SE	
Gouland Downs	12 - 26	N/A	N/A	Marchant & Higgins (1990)
Saxon area	10 - 42	23.0	N/A	McLennan & McCann (1991)
Taramakau Valley	N/A	20.0	N/A	Eastwood (2002)
Hurunui North Branch	21 - 40	32.6	2.2	Keye *et al.* (2011)
Lake Rotoiti	10 - 66	34.4	9.4	This study

territories form a mosaic of adjacent circular/oval-shaped areas (McLennan & McCann 1991; Robertson *et al.* 2005), whereas in the mountains of Arthur's Pass–Hurunui territories extend from valley floors to the mountain tops and are defined by geological features (Wylie & Nelson 2010).

A spatial pattern of territories similar to the Arthur's Pass–Hurunui region probably occurs in the RNRP. Family 3 clearly occupied only a single spur as their locations were often close to streams in gullies either side of the spur, but never beyond them. This suggests that these swift flowing streams may pose an obstacle to kiwi movement and delineate some kiwi territories. However, these streams only flow strongly over winter and adult kiwi have crossed them when establishing new territories after translocation. Given the large size of each truncated spur and adjacent gentle slopes, more than one territory can probably be present on a spur. Another kiwi family, not radio-tagged but regularly located by DOC staff using a trained dog, occupied a territory on the same spur as Family 3. The territory of this non radio-tagged family extended into higher altitudes, from the top of the spur up to the tree line. The lower boundary of their territory probably abuts the upper boundary of the territory of Family 3. Similarly, past observations by DOC staff suggest that the spurs above the territories of Families 1 and 2 can support other kiwi, but there are currently no radio-tagged birds living there.

Movement analysis

Analysis of kiwi movement within their home ranges was conducted based on distances between their roosting sites. However, Laundré *et al.* (1987) pointed out that distance between daily relocation data for nocturnal species is more a measure of site fidelity than a measure of relative or real movement as many animals may travel around their home ranges and then return back to the same roost. Therefore the distance between roosting sites conveys mostly information about the internal structure of territories and patterns of roosting sites. In all home ranges there were observed distinct areas of clumped location points, but the significantly higher mean distance (one-way ANOVA: $F = 4.40$, $df = 2, 140$, $P = 0.014$) between the roosting sites of Family 3 suggests that Onahau, Tai Tapu and Chick 5 travel between their favourite spots more often, whereas the members of Families 1 and 2 spend longer periods roosting in one restricted location and move between such favourite locations less often. Incremental area analyses also show that the home ranges of Onahau and Tai Tapu reached their asymptotes much earlier, at 7 and 11 location fixes, respectively, as these birds travelled around their home range and roost at different locations more often. The home ranges of members of the other families appeared to reach their assumed asymptotes several times, because these kiwi stayed longer at each location, so multiple consecutive location fixes did not increase the computed home range. This suggests that a variety of movement and site fidelity patterns exist among families and great spotted kiwi do not use their roosting sites randomly, as shown for North Island brown kiwi (McLennan *et al.* 1987).

If a home range suddenly increases after an area-observation curve reached its asymptote as a result of the long-term movement patterns, a question is raised about how many locations is sufficient for accurate home range estimation. Seasonal differences exist in the spatial composition of great spotted kiwi roosting sites (McLennan & McCann 1991) and similar observations have been made in other kiwi species (Gibbs & Clout 2003). McLennan and McCann (1991) found that higher-altitude areas were preferred for roosting in winter but feeding often took place in the low-lying areas of their territory during the night. Therefore the winter home range of Family 3 may extend closer to the lake than our home range estimates show. It is possible there are differences in summer and winter home ranges and future home range research could investigate possible differences between seasons.

Association between adults and subadults

The home ranges of adults and subadults and repeated co-location of them in burrows has revealed hitherto unknown associations between them. It is becoming obvious that subadults interact with the parents much longer than expected. These results show subadults occupying the same territory as their parents at 2.5 years old and, at least for some subadults, probably even 4.5 years old.

The oldest subadult shared 78% of its MCP home range with its mother, Anatoki, and in 50% of observations roosted within 50 m of her roosting site. The father was unknown or not present. Chick 5, at 2.5 years old, shared 99% of its home range with its parents and it was found within 50 m of their roosting site in 72% of all observations. These were the only offspring of the parents at the time. Whether this translates into direct parental input into offspring rearing over an extended period of time is unknown. It has been suggested that extended parental care probably does not affect regular breeding of adults, who tolerate an older subadult in their territory even though it is not known to contribute to the rearing of younger offspring (Wylie & Nelson 2010). Family groups of adults and subadults of various ages exist in Stewart Island tokoeka, but those subadults contribute towards the rearing of younger offspring (Colbourne 2002). In contrast, juvenile North Island brown kiwi leave the natal territory within 3–9 weeks of hatching (Burbidge *et al.* 2003; Robertson & Colbourne 2003). The role of maturing subadults within the territory of great spotted kiwi pairs remains unclear, but assistance with incubation appears unlikely or a rare occurrence, as subadults have not been found in nests either on an egg or with an incubating adult (GH, *pers. obs*.), unlike southern tokoeka (Colbourne 2002).

Although our data are limited, there was a tendency for subadults to roost further from parents with age. The youngest subadult, Chick 7, roosted within 400 m of its parents in all the observations. As the chicks matured they tended to roost further away. Roost sharing in family groups is not confined to the RNRP. A juvenile about a year old, weighing 1.5 kg, was found sharing a roost with its father in the Gouland Downs during an egg transfer operation in 2009. It was located a year later sharing a roost under gahnia (*Gahnia rigida*) with both parents. In Arthurs Pass, a family group of 2 adults, a year old subadult and a recently hatched chick have also been found roosting together (S. Forder, *pers. comm*.). The age at which subadults eventually leave the natal territory is unknown. Subadults at the Gouland Downs gradually replace adults in the territorial structure (Robertson *et al.* 2005). It also remains unclear if subadults would be able to remain in the parental territory if the surrounding area is tightly partitioned into territories of other adult birds, and thus resources more limited, as it is in the Gouland Downs. Little spotted kiwi (*Apteryx owenii*) reduced territory size when a population density had increased (Robertson & Colbourne 2004), but further research on subadult dispersal for great spotted kiwi is required.

Although this study was carried out on a small sample, the results suggest that great spotted kiwi have substantially greater association with their offspring than most other kiwi species except possibly southern tokoeka (*Apteryx australis*; Colbourne 2002) as offspring associate with the parents for up to 4.5 years and possibly longer. Whether there is any assistance of the subadults by parents during this time is unknown. Until recently it was assumed that great spotted kiwi chicks left the natal area soon after hatch (McLennan 1990) so this information has implications for management of the species. For example, the Operation Nest Egg programme was developed for North Island brown kiwi (*Apteryx mantelli*, Colbourne *et al.* 2005), where the chick is largely independent within a few weeks of hatching. To apply this model to the great spotted kiwi with little modification for possible requirements for extended parental association may lead to problems with releases of hand-reared chicks.

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