

## Home range size of kakapo (*Strigops habroptilus*) on Codfish Island

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Conservation management of kakapo (*Strigops habroptilus*) is undertaken presently on three islands in southern New Zealand (Eason *et al.* 2006; Elliott *et al.* 2006). Key management questions include what is the carrying capacity of island habitats and what are the home range sizes of individual birds?

Home range, defined as "that area traversed by the individual in its normal activities of food gathering, mating and caring for young" (Burt 1943), contains those resources that an individual requires for survival, such as adequate food and shelter. These may vary with age, sex, breeding condition or environmental conditions (McFarland 1987). Previous studies of kakapo home range have recorded varied sizes; 15 - 50 ha (Stewart Island; Best 1985), 21 - 38 ha (Little Barrier Island; Moorhouse 1985), 0.81 - 29.22 ha (Maud Island; Trinder 1998), and 0.75 - 11.4 ha (Pearl Island; Trinder 1998). Overlap and non-exclusive use of home ranges have been recorded (Merton *et al.* 1984, 1999; Moorhouse 1985), and Moorhouse (1985) noted that females occupied larger home ranges than males (10 - 20 ha larger, although this difference was not statistically significant).

We measured home range sizes of adult female and juvenile kakapo on Codfish Island / Whenua Hou (1396 ha: Lat. 46° S, Long. 167° 38° E), located 3 km north-west of Stewart Island. A nature reserve since 1986, the island's predominant habitat type is a podocarp / rata (*Metrosideros umbellata*) forest, covering approximately 70% of the island. All kakapo, including fledged young, carried a 20 - 35 g back-mounted radio transmitter, allowing for their location to be established using radio tracking techniques. The data upon which this study was based comprised point-location radio-fixes obtained by

triangulation (Mech 1983)) using a *Telonics* TR4 radio receiver, (Telonics, Arizona, USA) and a hand-held three-element *Yagi* antenna (Sirtrack, Havelock North). These data were collected predominantly during the day when the birds were roosting and immobile, following the assumption of Moorhouse (1985) that roost sites are a direct reflection of an individual's movements and, therefore, of its home range. Additional data, collected by Department of Conservation staff between September 2001 and January 2002, were also used in this study.

Home range estimates were determined using the minimum convex polygon (MCP) and Kernel methods (95% and 50% kernels) (Hooge & Eichenlaub 1997). MCP is one of the most widely-used methods of estimating home range (Harris *et al.* 1990; Seaman *et al.* 1999; Vangen *et al.* 2001) and has been used in previous kakapo studies (Trinder 1998). Kernel density estimators are increasingly being used in home range analysis and are considered to be among the more reliable methods for home range analyses (Worton 1987; Seaman & Powell 1996). We used a fixed kernel and least squared cross-validation (LSCV) technique to determine the amount of smoothing (Seaman *et al.* 1999). Different parts of home ranges are used disproportionately, with activity often concentrated in core areas (Harris *et al.* 1990). The kernel method was used to determine these core areas, using 50% kernels, a widely-used core area estimate.

All home range estimates were derived using the computer programme "*Animal Movement*" (Hooge & Eichenlaub 1997). Data analyses were performed using the computer programme "*R*" (Ihaka & Gentleman 1996). Paired t-tests and Welsh two sample t-tests were used, once normality had been confirmed, to compare home range sizes between sexes, between ages, and between hand-reared and wild-reared juveniles.

Home range estimates for each adult female kakapo ( $n = 13$ ) were determined during two periods, September 2001 - January 2002 and September 2002 - January 2003. Home ranges were also calculated for 13 wild-reared juveniles from their date of dispersal (commencing September 2002) to January 2003. This allowed direct comparison between mothers and juveniles, and between adult females with and without chicks (Table 1). We analysed data only from those birds for which >10 locations were recorded. Home ranges of three hand-reared juveniles released onto the island were also determined.

**Table 1** Mean home range size ( $\pm$  *sd* (range)) of adult female and juvenile kakapo on Codfish Island, as determined by minimum convex polygon and kernel methodology.

Group	Mean no. fixes/bird	MCP (ha)	95% kernel (ha)	50% kernel (ha)
Adult females (Sept. 2001 – Jan. 2002) ( <i>n</i> = 13)	28	14.0 $\pm$ 11.0 (5.1 – 44.0)	19.5 $\pm$ 25.3 (5.9 – 100.4)	3.4 $\pm$ 7.1 (0.7 – 26.6)
Adult females (Sept. 2002 – Jan. 2003) ( <i>n</i> = 13)	71	15.6 $\pm$ 7.3 (5.6 – 27.8)	13.8 $\pm$ 6.3 (6.8 – 25.1)	1.6 $\pm$ 0.7 (0.7 – 2.5)
Wild-reared juveniles ( <i>n</i> = 13)	30	14.9 $\pm$ 8.6 (3.0 – 31.1)	20.3 $\pm$ 13.1 (5.1 – 50.5)	3.0 $\pm$ 2.1 (0.5 – 7.1)
Hand-raised juveniles ( <i>n</i> = 3)	50	23.2 $\pm$ 5.6 (16.8 – 26.6)	21.7 $\pm$ 6.3 (14.4 – 25.3)	3.2 $\pm$ 2.1 (1.0 – 5.2)
Female juveniles ( <i>n</i> = 9)	35	16.99 $\pm$ 7.7 (3.98–28.36)	19.5 $\pm$ 9.8 (5.73–36.37)	2.76 $\pm$ 1.9 (0.99–7.08)
Male juveniles ( <i>n</i> = 7)	31	15.4 $\pm$ 9.8 (2.96–31.14)	22.98 $\pm$ 14.8 (5.08–50.47)	3.52 $\pm$ 2.2 (0.52–6.45)

There was no statistically significant difference between mean female home range size in the two years (Table 1) for either MCP or all kernel estimates (MCP: paired *t*-test,  $\alpha = 0.05$ ,  $P = 0.644$ ; 95% kernel paired *t*-test,  $\alpha = 0.05$ ,  $P = 0.977$ ; 50% kernel: paired *t*-test,  $\alpha = 0.05$ ,  $P = 0.342$ ).

There was no statistically significant difference between home range sizes of wild-reared and hand-reared juveniles (MCP: paired *t*-test,  $\alpha = 0.05$ ,  $P = 0.099$ ; 95% kernel: paired *t*-test,  $\alpha = 0.05$ ,  $P = 0.79$ ; 50% kernel: paired *t*-test,  $\alpha = 0.05$ ,  $P = 0.85$ ) or between home range sizes of male and female juveniles (MCP: paired *t*-test,  $\alpha = 0.05$ ,  $P = 0.78$ ; 95% kernel: paired *t*-test,  $\alpha = 0.05$ ,  $P = 0.70$ ; 50% kernel: paired *t*-test,  $\alpha = 0.05$ ,  $P = 0.058$ ). Based on these non-significant results, hand-reared, wild-reared, male and female data were pooled for further analyses.

Home range sizes of juveniles and adult females in 2002–2003 did not differ significantly using MCP and 95% kernels as estimators (MCP: paired *t*-test,  $\alpha = 0.05$ ,  $P = 0.75$ ; 95% kernel: paired *t*-test,  $\alpha = 0.05$ ,  $P = 0.062$ ). However, using 50% kernels a statistically significant result was observed (50% kernel: Welch two sample *t*-test,  $\alpha = 0.05$ ,  $P = 0.1403$ ), with adults having smaller home ranges than juveniles.

The similarity of adult female home range sizes in a non-breeding and a breeding year suggests that rearing young does not require expansion of a female's home range. It is possible that a breeding female's home range may have been larger when her chick(s) were entirely dependent on her for food (from hatching until they start feeding for themselves). However, by September, any such effect was not apparent and we found then that the home ranges of two mothers no longer included their nest sites.

The larger juvenile home ranges could be due to a number of factors. For example, the smaller number of locations used

to estimate home range size could have led to over-estimation of home range area (Seaman *et al.* 1999); the home range estimates may have included movements outside of the area in which they eventually settled thus inflating the home range size; juveniles may not have settled at all and may still have been making exploratory movements; and juveniles may have differing requirements from adults, perhaps needing resources with different mineral, vitamin or fat content and to obtain these juveniles wandered more widely. Another possibility is that young may have been pushed into inferior habitat, thereby needing larger home ranges to meet all of their requirements. It has been argued that home range size is largely a function of resource requirements and availability (Boutin 1990; Davies & Lundberg 1984).

We determined considerable overlaps of individual home ranges using both the 50% kernel and the MCP method. The overlaps between individual kakapo were probably greater than we recorded because the home ranges of sub-adults, males and unfledged juveniles were not considered. These home range overlaps are of interest, as kakapo are generally presented as being solitary animals (e.g., Heather & Robertson 1996). Historical accounts e.g., Buller (1873) suggested kakapo could often be encountered in small groups outside the breeding season, and there are modern observations of this also.

For example, small groups of kakapo have been found roosting very close to each other, including a female roosting next to the nest of a breeding female, and young males roosting near older males during the breeding season (Climo & Ballance 1997). On Codfish Island, adult males and juvenile females have roosted in close proximity, with one instance of an adult male and a juvenile female found roosting in the same tree (J. Joice, D. Eason pers. comm.). Females have also been noted occasionally forming loose, temporary associations with other females (D. Merton pers. comm.).

**ACKNOWLEDGEMENTS**

Many thanks to the Department of Conservation and Auckland University for financial and logistical support and to the Kakapo Protection Officers and volunteers on Codfish Island for support and help in data collection.

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**Keywords** Kakapo; *Strigops habroptilus*; home range