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Satellite tracking a New Zealand falcon (*Falco novaeseelandiae*)

JOHN D. HOLLAND
REBEKAH R. McCUTCHEON
Institute of Natural Resources, Massey University, Private Bag 11-222, Palmerston North, New Zealand
J.D.Holland@massey.ac.nz

Abstract We report the 1st use of a satellite transmitter to track the endemic New Zealand falcon (*Falco novaeseelandiae*). The movements of an adult female bush falcon in Kaingaroa Forest east of Lake Taupo, central North Island were monitored during a 3-year period from Feb 2002. The geolocations of the falcon were mapped and revealed that the falcon remained close to her nesting territory throughout the study. The home range included an area of *c*.200 km^2. The falcon nested in pine compartments (0-3 years old) for 3 consecutive years; her nests averaged 5 km apart. After nightfall the falcon was located within the 95% isopleth of her home range, highlighting her sedentary nature. During the breeding season the falcon appeared to wander outside of her home range, with the furthest recorded distance from its centre being 137 km. Throughout the 3 years, observations suggest the falcon preferred to stay close to open areas, which may be related to the frequency of hunting opportunities.

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Keywords New Zealand falcon; *Falco novaeseelandiae*; satellite tracking; home range; distribution; exotic forest; Kaingaroa Forest

INTRODUCTION

The endemic New Zealand falcon (*Falco novaeseelandiae*), is the only falconid and the rarer of the 2 diurnal raptors in New Zealand. The falcon has been fully protected only since 1970 (Heather & Robertson 1996), and its low population has been attributed to habitat loss after the arrival of Europeans, introduced predators, persecution, and pesticides. Three "forms" of the falcon are recognized: bush falcon (North Is and north-western South Is), eastern, and southern. The New Zealand Department of Conservation status classification for the bush falcon is Class 3 (nationally vulnerable), for the eastern falcon it is Class 5 (gradual decline), and Class 2 for the southern falcon (Department of Conservation 2005). Fox (1977, 1978a,b) considered the falcon to be in marked decline. The falcon is susceptible to disturbance and predation during nesting and it is difficult to determine whether the decline in numbers results from lower productivity or increased mortality (Fox 2001, cited in Hyde & Stewart 2002). Fox (1978b) estimated that there were 450-850 breeding pairs of bush falcon, nesting mostly in remote hill country, in podocarp or beech forests: little was known about populations resident in exotic forests.

To assist with efforts aimed at the conservation of the falcon, information is needed on the size of their home range and their seasonal movements. Previous studies of the movements of New Zealand falcons have employed banding techniques (Fox 1978a). However, banding normally provides information only on where the bird was trapped and where it was recovered, unless there are live recapture and release records. The recently-developed technology of satellite telemetry, however, provides a more-or-less continual stream of location data which allows the bird's location to be plotted daily. Satellite location technology has been used so far on various migratory birds, including various species of albatross (*Diomedea*, *Thalassarche*, *Phoebastria* spp.), Wahlberg's eagle (*Aquila wahlbergi*), and the peregrine falcon (*Falco peregrinus*) (Argos 2007). Early satellite tracking transmitters were too heavy to be used on the New Zealand falcon, but more compact, lighter, solar-powered transmitters have now been developed. In 2000, JH acquired suitable equipment and established the New Zealand Falcon Research Programme (NZFRP). In Feb 2002, a transmitter was harnessed to an adult female New Zealand falcon (of the small, dark form known as the bush falcon; Fox 1978a), in an effort to determine its movements, home range, and behaviour in forests of introduced (northern hemisphere) pines (*Pinus* spp.).

The bird was found nesting in the Kaingaroa Forest, a commercial (predominantly *Pinus radiata*) pine plantation east of Lake Taupo in the central North Is. This was unusual, because historically the falcon was known to nest only in tall lowland

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podocarp forests in the North Is (Stewart & Hyde 2004). Using the Argos System®, this female falcon was tracked intermittently for 3 years.

METHODS

Study site

Kaingaroa Forest is one of the oldest and largest softwood plantation forests in the world and lies east of Taupo on the central North Is pumice plateau, New Zealand (Kaingaroa Timberlands Ltd 2005). The forest stretches about 100 km from southeast of Rotorua to the Kaimanawa ranges south of the Napier-Taupo highway. The forest is on a plateau with a gently rolling topography, at 450-650 m a.s.l (McCarthy 2004). Soils on the plateau are mainly Kaingaroa and Kawhatiwhati sands (McCarthy 2004). Much of the surrounding land is in agricultural production on the flat areas and native vegetation on the Kaimanawa and Urewera ranges, bordering the plantation.

In 2002 Kaingaroa Forest consisted of more than 152,000 productive ha (Colin Maunder, pers. comm. 2006), with *Pinus radiata* the predominant species (over 90%). The forest is dissected by roads and firebreaks to form some 1,400 compartment blocks of similar sizes, averaging *c*.100 ha, but up to 363 ha (Caithness *et al*. 1989; Hyde & Stewart 2002). The forest is therefore a continuously changing mosaic of stands, ranging from clear-felled areas, newly planted to mature 30-year-old trees, with a diverse vegetation growing between most stands and road margins (Caithness *et al*. 1989). Every year about 11,000 ha of clear-felled areas have been replanted within Kaingaroa (Hyde & Stewart 2002).

The climate is mild. During the 3-year study, annual precipitation averaged 1340-1610 mm, reasonably evenly distributed throughout the year, and with the highest rainfall during Jun and Dec. Jul was typically the coldest month, with temperatures of 3.6-12.8°C: Jan was the warmest (10.8-26.2°C) month. Winters are cold, light snow is common, and from Mar to Nov ground frosts of -5 to -10°C are not unusual. The plateau is exposed to prevailing westerly and southerly winds (Boyd 1992; McCarthy 2004).

Satellite tracking

A 540g adult female New Zealand bush falcon *Falco novaeseelandiae* was fitted with a solar-powered satellite platform transmitter terminal (PTT) weighing 18 g. The PTT was programmed with a 10 h on, 24 h off-duty cycle to minimise satellite charges while still gathering sufficient data during the study period. We received intermittent co-ordinates from the transmitter until 11 Dec 2004.

To assist with the design of the Teflon™ tube harness and to ensure the arrangement was safe and did not restrict the bird's movement, the harness and a dummy PTT were tested on a captive bird at Massey University. From these tests, the handling time between capture and release was estimated to be *c*.30 min.

A transmitter should weigh no more than 5% of the bird's body weight (Aldridge & Brigham 1988) so as to not adversely affect its flight performance and natural activities. The 18-g solar-powered Platform Transmitter Terminal (PPT) (Microwave Telemetry Inc, Columbia, Maryland, U.S.A) included a small solar panel array to charge its internal battery, which had a life expectancy of at least 3 years. The transmitter unit incorporated a temperature sensor and a voltmeter for the battery. With this 18-g transmitter, the study bird had to weigh at least 350 g, which meant that a large female was required (male falcons weigh 252-500 g, and females 420-594 g; del Hoyo *et al*. 1994). A falcon of the correct weight was found after 4 months of searching between Rotorua and Wellington. The female of a nesting pair found in Kaingaroa Forest by Geraldine Moore (Massey University) was captured on 16 Feb 2002, using bait birds and Bal-chatri and Deghaza traps (Bloom *et al*. 1987). Standard measurements were taken, the bird banded, and the transmitter and harness fitted, and the bird released in its home range.

The Argos® System satellite-based location and data collection system (Service Argos Inc. 2005) can locate a PTT within <150 and <1000 m of the transmitter's actual location. The accuracy of each location depends on whether the bird carrying the transmitter is in light or dense vegetation and on weather conditions, which can affect the charge and signal of the solar-powered device. The clearer the weather, and the less vegetation cover, the more accurate the locations.

The Argos receivers were carried by National Oceanic and Atmospheric Administration (NOAA) satellites in polar orbit (Cohn 1999; Service Argos Inc. 2005). At an altitude of *c*.800 km these satellites had *c*.5000 km diameter visibility circles. The Argos system normally requires 4 transmissions from the PTT during a satellite overpass to derive a location. However, special processing for wildlife research can derive locations from as few as 2 Doppler measurements. The average duration of transmitter visibility during a pass was 10 min. The data were re-transmitted to ground stations in Alaska and Virginia (USA) and Lannion (France), the information processed and made accessible to the researcher via the Internet. Each location point was assigned to a standard location class (LC, Service Argos Inc. 2005) with estimated accuracies of: LC3, ≤ 150 m; LC2, ≥ 150 m < 350 m; LC1, ≥ 350 m < 1000 m; LC0, A, B, and Z locations had failed quality assurance tests and no estimate of accuracy was provided for them (Service Argos Inc. 2005).

Data analysis

Data on the falcon's location were received

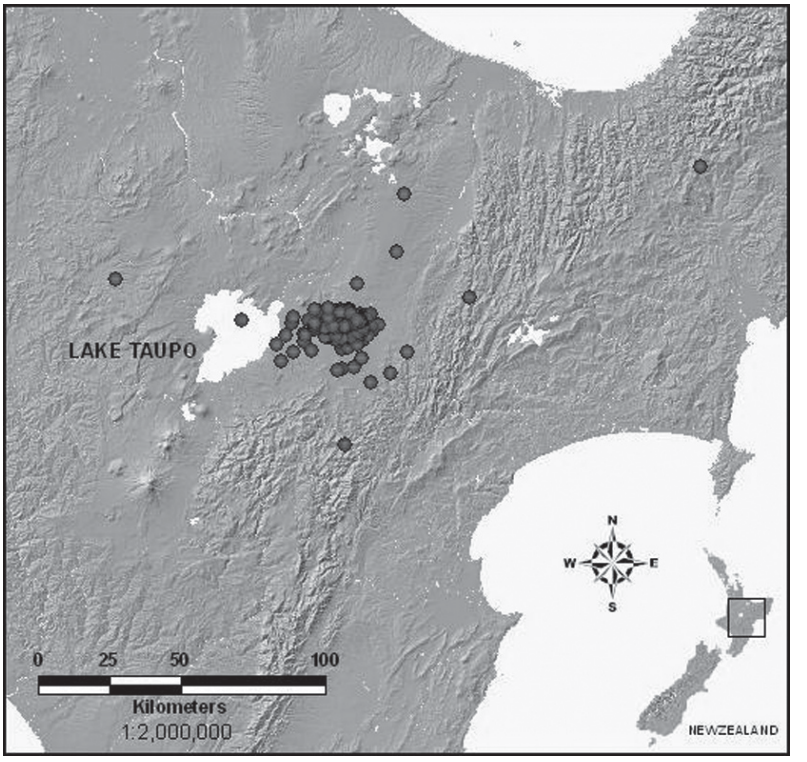

Fig. 1 Satellite up-link locations of tagged adult female New Zealand falcon (*Falco novaeseelandiae*) in the Kaingaroa Forest, central North Island, New Zealand from Feb 2002 to Dec 2004.

intermittently from Feb 16 2002 until Dec 11 2004. Locations received were subjected to several stages of quality control. Initially, location LC A, B, and Z estimates were removed, leaving 812 points, in classes LC0 to LC3. These 812 locations were mapped using ArcMap™ 9.1 (ESRI®, ArcView GIS) Geographical Information System software. Because the female falcon proved to be sedentary, locations with potential errors >1 km were unacceptable so all LC0 points were removed, leaving 332 points.

The data included long periods when either no transmissions were received or the location points had unacceptably low levels of confidence. No data were received for Mar-Jun 2002, Jun-Jul 2003, Mar-Apr 2004, Jun-Oct 2004 and occasional LC0 location points were included to assist the analysis. These breaks in the sequence may have resulted from problems with the pre-programmed duty cycle.

The Animal Movement (SA v2.04 beta) extension to ArcView 3.2 was used for the home range analysis. We used Fox's (1977) model of the "stages in the reproduction cycle of a hypothetical, average, successful pair of eastern falcons" as a guide to the duration of each stage in this bird's annual cycle. "Breeding season", defined as the period of *c.*100 days when the falcon pair defended a nesting territory, was predicted for each year. Yearly home ranges were defined to run from Jun and Jun the following year, to provide a buffer around the bird's general breeding season (Oct 1-Mar 31) and therefore to ensure that points included were associated with a single nest site. The non-breeding season was defined as 1 Apr-30 Sep. To estimate home range, we used the 95% isopleth of the distribution of use from kernel analysis, which represented the area where the bird was estimated to have spent 95% of its time. The 95% isopleth was chosen as the best representation of home range, rather than the 100% isopleth which includes large areas rarely or never visited by the bird.

Distance travelled (km) was calculated from each reliable (LC1, LC2, LC3) location estimate to the next, but the time between successive reliable location estimates varied greatly, from a few minutes to a few months. As a result, daily distances travelled and top speeds could therefore not be calculated from the satellite information. The bird's proximity to open areas was analysed using the LC3 points, those with the smallest predicted error, only. Measurements were made within ArcMap using the ruler function. Observations of the entire data set (332 points) were also made.

Weather data were recorded at the Matea Remote Auto Weather Station at 1200 h each day.

RESULTS

Distribution and home range

During the 3 years (2002, 2003, 2004), the female

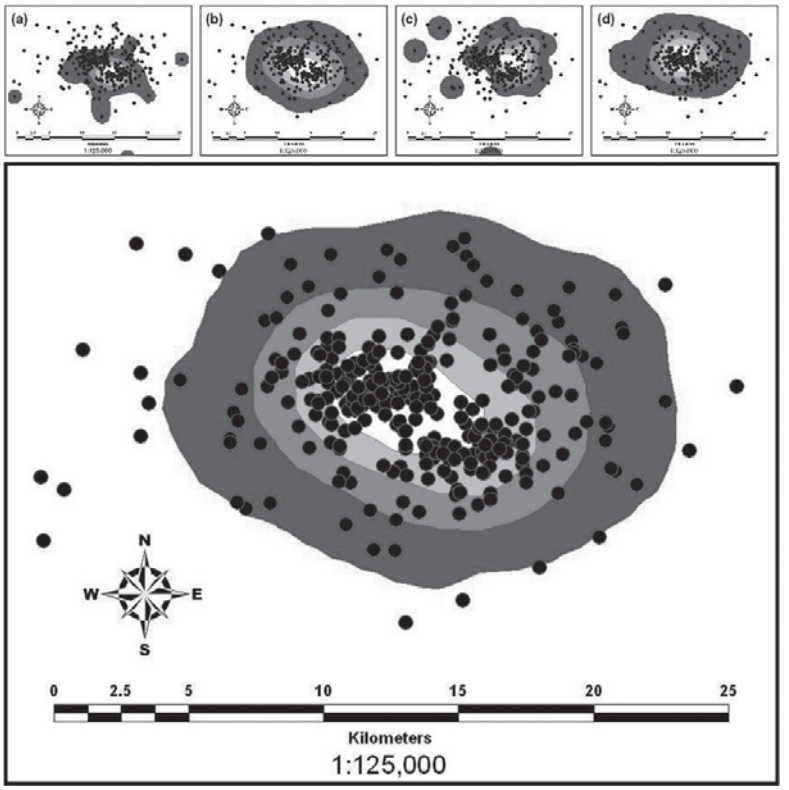

Fig. 2 Home range (95, 75, 50, 25% probability contours using fixed-kernel method) of a satellite platform transmitter-equipped adult female New Zealand falcon (*Falco novaeseelandiae*), as determined by up-links over 3 years from Feb 2002 to Dec 2004 in: a, non-breeding season 2002; b, breeding season 2002-2003; c, non-breeding season 2003; d, breeding season 2003-2004. Filled circles, 312 satellite telemetry locations.

falcon remained mostly close to her natal territory throughout the breeding and non-breeding seasons, and was recorded mostly within 5.8 km of the centre of her home range (Fig. 1). There was no evidence that she moved to an alternative wintering range. Twenty-six (7.8%) of the 332 locations were in areas of farmland with most of the rest being in the Kaingaroa exotic pine forest. Several were, however, in scattered patches of native forest within the pine forest, or further afield in native forest on adjacent ranges. Occasionally the bird ventured much farther (> 130 km) and then returned within 24 h: 7 locations (2.1%) were >30 km from the centre of her home range (Fig. 1). Only 1 location with acceptable accuracy was received during the 2004 non-breeding season, so the bird's home range could not be calculated for that year.

The 95% home range isopleth during the 3 years the bird was tracked included an area of 201 km^2, within an oval *c*.19 km east to west and 14 km north to south (Fig. 2; Table 1). During this time, she spent 25% of her time within 17 km^2. Her home range from Feb-Jun 2002 was 20.4 km^2 and from Jun 2003-Dec 2004 she used 11.7 km^2 (Table 1). The apparently small home ranges may, however, have been an artifact of the limited number of data points for these periods. Between Jun 2002 and Jun 2003, the estimated home range was 200.6 km^2, which was similar to the 210.6 km^2 used from Jun 2003 to Jun 2004 (Fig. 3, Table 1).

During the non-breeding season (1 Apr-30 Sep) the locations indicated that the bird remained within the area where she had bred before, but included a smaller, irregular 95% isopleth area (109.4 km^2 in 2002; 162.5 km^2 in 2003; Fig. 2, Table 1).

Of the 332 location points, 45 (13.6%) were recorded between 2200 h and 0400 h. Of these night locations, only 3 (6.7%) were outside the 95% isopleth of the overall home range, but they were only just outside that boundary.

The furthest location recorded was west of Tolaga Bay, on the east coast, bordering the Ruakumara Ranges, 137±1.0 km northeast of the centre of her home range, at 1600 h on 2 Dec 2002 (Table 2). By 2045 h on the same day, she had traveled 161 km (± 2) to a point southwest of her home range. During this time, the weather was clear, with a temperature of 19ºC and a 14 kmh^{-1} crosswind from the southeast. If the location data were correct, she had flown at least 161 km, equivalent to a straight line average speed of 34 kmh^{-1} (Fig. 1).

The fastest movement recorded for this female was 77 km in 1 h 38 min, a still-air, straight-line speed of 47 kmh^{-1}. This was to the west of the Pureora State Forest Park on the western side of Lake Taupo, on a clear day with a temperature of 16°C, and with a light (12 kmh^{-1}) crosswind. Excluding the 5 extremes (Table

Table 1 Description of the 25% and the 95% isopleth home range for the satellite-tracked female New Zealand falcon (*Falco novaeseelandiae*) in each year, during breeding and non-breeding seasons.

		25% Isopleth		95% Isopleth	
Season / period	Points used	Area (km^2)	Dia E-W / N-S (km)	Area (km^2)	Dia E-W / N-S (km)
Breeding					
Feb-Jun 2002	4	1.6	n/a	20.4	n/a
Jun 2002-Jun 2003	207	17.8	5.5 / 3.9	200.6	18.9 / 14.0
Jun 2003-Jun 2004	114	15.3	4.7 / 4.1	210.6	21.6 / 12.8
Jun-Dec 2004	7	0.8	n/a	11.7	n/a
Non-breeding					
Apr-Sep 2002	34	5.9	n/a	109.4	n/a
Apr-Sep 2003	33	10.4	n/a	162.5	n/a
Apr-Sep 2004	1	-	-	-	-
Combined 3 years	332	16.6	5.6 / 3.9	201.0	19.1 / 14.1

Table 2 Distances between the nest sites of the satellite-tracked female New Zealand falcon (*Falco novaeseelandiae*) in km, for each year of the study: Nest 1 (2001-02); Nest 2 (2002-03); Nest 3 (2003-04); possible Nest 4 (2004-05).

Nests	1	2	3	4
1	0	4.843	0.432	7.348
2		0	4.731	5.097
3			0	7.541
4				0

2), the points outside the 95% isopleth averaged 15.2 km from the centre of the home range.

Nest sites and breeding season

Throughout the 3 years of the study, the female nested within Kaingaroa forest and bred late in the season. Nest 1 (where she was caught), was within the clear-felled compartment 577, which was surrounded by commercially mature stands (Fig. 3). Two fledged juveniles, 1 male and 1 female, estimated to be 45 days old, were observed near the nest so her breeding season was estimated to be from mid-Nov 2001 to mid-Feb 2002.

Ten months later, Nest 2 (Table 3) was found 4.8 km southeast of Nest 1 on the boundary of a mature stand of pine and the clear-felled compartment 566. Three 21-day-old chicks were banded at Nest 2 on 14 Dec 2002. She had bred over a month earlier than in the previous year. Nest 3 was < 500 m south of Nest 1, in a neighbouring compartment (584)of 2-year-old pines. On 22 Dec 2003, there were 2 eggs. Unfortunately the nest failed later. Her estimated breeding season was from late Nov 2003 to early Feb 2004, which was later than previous attempts. In Dec 2004, we could not find her nest. However, the cluster of locations during her normal breeding period suggested she had attempted to nest at a site *c.*7.5 km east of Nests 1 and 3, in an area bounded by large blocks of mature pines, a clear-felled compartment, and the Rangitaiki River.

Table 3 Direction from home range, distance (km maximum location error) and signal accuracy rating (signal) for the most distant locations (> 40 km from centre of home range) for satellite-tracked female New Zealand falcon (*Falco novaeseelandiae*) in the central North Island, New Zealand, in 2002-2004.

Date	Direction	Distance	Signal
20 Nov 2002	North	51 ± 0.7	LC 2
2 Dec 2002	Northeast	137 ± 1.0	LC 1
16 Oct 2003	West	81 ± 0.7	LC 2
12 Dec 2003	South	41 ± 1.0	LC 1
13 Feb 2004	Northeast	45 ± 1.0	LC 1

Proximity to open areas

The data suggest that, more often than not, the female falcon was close to a forestry track, road, skid pan, or clearing. Of the LC3 points recorded, 62% were within 50 m of an open area. The general impression was that most locations were similarly close to open areas, but because of the lower reliability of many locations, this trend could not be quantified

DISCUSSION

Distribution and home range

Based on banding recoveries, Fox (1977, 1978a) considered the New Zealand falcon to be sedentary. He postulated that most established adult pairs remained in their home range throughout the year, and possibly continued to defend their breeding territory. Our data confirmed that this female falcon was sedentary. Throughout the 3 years we

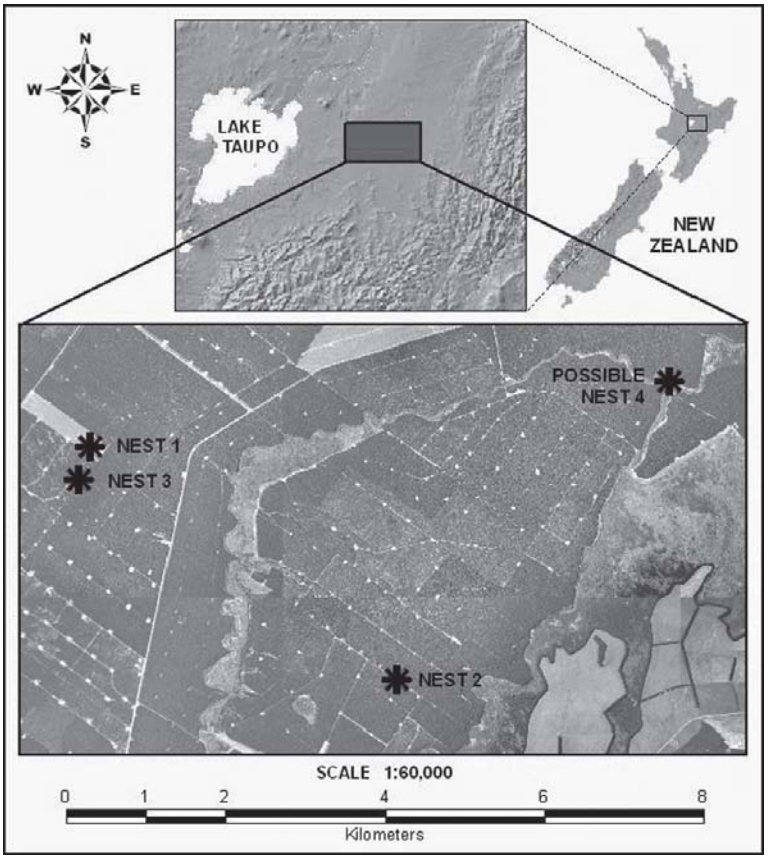

Fig. 3 Location of nest sites used by an adult female New Zealand falcon (*Falco novaeseelandiae*) in Kaingaroa Forest, central North Island, New Zealand, from 2001 to 2005. Nest 1, 2001-2002; Nest 2, 2002-2003; Nest 3, 2003-2004; possible site for Nest 4 (2004-2005.

tracked her, the bird remained close to or within her generalised breeding area during both the breeding and the non-breeding seasons. Indeed, after nightfall the falcon was always located within or near her 95% isopleth home range. This behaviour is similar to that of most falcon species: relatively few species, including the peregrine (*Falco peregrinus*), the saker (*Falco cherrug*), and lesser kestrel (*Falco naumanni*) are known to migrate.

The satellite-tracked New Zealand falcon spent most of her time within Kaingaroa Forest, rarely venturing out into the neighbouring farmland (7.8% of locations). When she was located outside of Kaingaroa Forest, she appeared to stay close to forested areas, generally in native forest-covered ranges, and seemed to prefer close cover. The density of prey in Kaingaroa Forest must have been sufficiently high to support her (and presumably her mate) there permanently. Monoculture plantation forests have been considered to support lower diversities and numbers of birds than do mixed forest associations (Clout & Gaze 1984). Our findings suggest that even a species such as the New Zealand falcon can adapt to living in and around such vegetation, provided there are sufficient edges and open spaces for hunting (given the association of locations with forest edges). Despite being largely sedentary, the female occasionally ventured more than 130 km away, but returned within 24 h.

Previously, the home ranges of New Zealand falcons have been difficult to measure. Fox (1978a) estimated that the home ranges of falcons in forested areas occupied 40-190 km^2 whereas home ranges in open grasslands could be as small as 15 km^2. The 95% isopleth defining this female's home range during the 3-year study included an area of *c.*200 km^2, which included stands of pine of varying ages, clear-felled areas, young stands of pine, and open areas (skid pans, access roads). Other studies of raptors suggest that falcons are particularly efficient hunters in open areas, and therefore their territories are smaller in open than in dense forest (Southern & Lowe 1968). However, food availability remains critical. If New Zealand falcons are indeed more efficient hunters in the open, and given the large proportion of mature pine stands in this female's home range, it may explain why her home range was larger than Fox's (1978a) estimate for New Zealand falcons in forest. Both Fox (1978a) and Newton (1979) suggest that home range size in

falcons is limited by the area which resident birds can patrol, or determined by the number of feeding places available and the distance between them.

Falcons have relatively narrow, pointed wings, which allow them to fly, glide, and dive at high speed. Peregrine falcons are believed to be the fastest birds, and are said to reach stoop speeds of up to 320 kmh^{-1} (White *et al*. 2002). Measurements of level flight speed suggest that the peregrine does not normally exceed 100 kmh^{-1} but it may be capable of bursts of higher speed (Ratcliffe 1980). The fastest transit speed recorded for the female falcon in this study was 77 km in 1 h 38 min, for a minimum speed of 47 kmh^{-1} with a 12.2 kmh^{-1} crosswind. In that time, the falcon could have flown much farther than the straight line distance between the locations. New Zealand falcons chase and catch racing pigeons (*Columba livia*), which weigh *c*.500g and can achieve groundspeeds of 75-100 kmh^{-1}.

Nests sites and breeding season

The data suggested that the female falcon preferred a particular area within Kaingaroa Forest; all her known nests were were within 5 km of each other. Similar behaviour, known as continued occupancy, is known in other raptors. Golden eagles (*Aquila chrysaetos*), white-tailed eagles (*Haliaeetus albicilla*), peregrines, and gyrfalcons (*Falco rusticolus*) are all known to have used particular cliffs successively over many years. Some species may even remain faithful to particular trees or patches of forest over many generations (Newton 1979). Recent reports from other areas of Kaingaroa Forest confirm that bush falcons are breeding successfully in exotic plantation compartments with trees 0-3 years old, which is consistent with the few historic reports and the findings of Hyde & Stewart (2002) and Holland (2004) and Noel Hyde, Steve Lawrence, Richard Seaton, and Debbie Stewart (all pers. comms). Plantation forests are felled and replanted in block rotation, so suitable, relatively open, sites for falcons are always available.

Each year this female nested later than most other falcons, both according to the breeding season estimates of Fox (1977) for the eastern falcon, and for others breeding in the Kaingaroa Forest (Holland 2004), and Noel Hyde, Steve Lawrence, Richard Seaton, and Debbie Stewart (all pers. comm.). We do not know why this female bred later.

Inter-pair distances

Distance between nests varies among raptors. Solitary species tend to have larger spaces between nest sites in comparison to colony species, who have a greater tolerance towards nests being close to their own (Newton 1979). Throughout the 3 years of the study, although other falcons were seen elsewhere in Kaingaroa Forest, no others were found nesting within the same compartment as the study female. This may have been the result territorial behaviour, limited prey availability in that compartment during the breeding season, or perhaps there were too few falcons in too much suitable nesting habitat for them to achieve high local nesting densities, (Richard Seaton, pers. comm.).

Proximity to open areas

Typically New Zealand falcons occupy territories that include a mosaic of forest and open country (Fox 1977; Marchant & Higgins 1990). New Zealand falcons hunt in the more open parts of their range, often in river valleys, where prey is more accessible (Fox 1977; Marchant & Higgins 1990), but occasionally in forest, particularly at the edges or where emergent trees or clearings break the canopy (Marchant & Higgins 1990; Moon 1992). Our observations for this female support these conclusions; the satellite locations were usually close to open areas.

Falcons in commercial pine forests

Before the discovery of 2 newly-hatched falcon chicks in a Kaingaroa compartment in 1994, little was known about populations of New Zealand falcons within exotic forests, and little is still known about the extent to which forestry management practices affect falcons (Hyde & Stewart 2002). From the 1930s, however, there have been anecdotal records and brief reports of falcons frequenting exotic pine forests (Buddle 1940; Edgar 1963; Jackson 1976; Johnson 1940; Ryder 1948) and bird population surveys in Whakarewarewa and Kaingaroa Forests listed the falcon as "not common but appears to be on the increase" (Weeks 1948). Over the past 70 years it is likely that falcons have continued to nest in small numbers in exotic forests, largely unnoticed or unreported. Fox did not investigate the falcons of the Central Plateau in the 1970s, but referred to records suggesting that Kaingaroa Forest supported a small breeding population (Hyde & Stewart 2002). Unpublished reports on Kaingaroa falcons have been prepared by Tootell (2002), Waugh (2002), Valentine (2004), Addison (2005), and McCutcheon (2005).

Mature monoculture exotic forests have not been recorded as being used for nesting by New Zealand falcons, possibly because of the dense, even canopy (Fox 1977, 1978a, b). However, both N. Addison (pers. comm.), and Richard Seaton (pers. comm.) found falcons nesting in 35-year-old pines, and in 5-year-old pines, respectively.

New Zealand falcons appear to be able to occupy managed exotic forests by using the clearings and cutovers from harvest rotation. Margins of clearings can have 95% more birds than comparable areas inside adjacent woodlands (Lay 1938, cited in Fox 1978a). These open areas provide a suitable nesting environment, suitable conditions for a variety of prey species, and therefore suitable hunting conditions for falcons. By making use of these

forestry areas, New Zealand falcons may well be extending their breeding range from neighbouring native forest areas (Hyde & Stewart 2002).

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