

Natal dispersal of New Zealand falcon (*Falco novaeseelandiae*) in plantation forests

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Abstract Natal dispersal of the New Zealand falcon (*Falco novaeseelandiae*) was documented using relocations of radio-tagged and colour banded falcons in Kaingaroa pine plantation. The age at which fledglings commenced natal dispersal was highly variable. The earliest fledglings dispersed 42 days after fledging, whilst others did not disperse out of their natal territories, remaining there to breed. After 91 days, 87% of fledglings had begun dispersal out of their natal territory. The mean time for the onset of dispersal was 76 days. Males generally dispersed earlier than females, but no significant difference was recorded. Both radio telemetry and colour band recoveries indicated that a large proportion of fledglings dispersed out of the study area. Mean natal dispersal distance within Kaingaroa Forest was 9.6 km. No significant difference was observed in natal dispersal distances between the sexes, although males generally roamed further afield than females. During this study, several females were recorded successfully breeding during their 1st year, a year earlier than usual. Males did not attempt to breed until they were 2 years old. We conclude that the high emigration rates and favourable breeding conditions in pine plantations make these habitats highly likely to act as source populations for neighbouring areas where populations of the New Zealand falcon may be in decline.

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INTRODUCTION

Natal dispersal is the movement of juveniles between their natal territory and their subsequent breeding territory (Greenwood 1980). For many non-migratory species natal dispersal is the furthest they will travel during their lifespan (Newton & Marquiss 1983; Wiens et al. 2006). Commonly, it is also a period during which high mortality occurs (Newton 1979). The causes for the onset of natal dispersal are varied and involve a complex variety of environmental and social factors (Clobert et al. 2001). Distances travelled during natal dispersal can vary widely between individuals, populations and landscapes (Wiens et al. 2006). Factors influencing

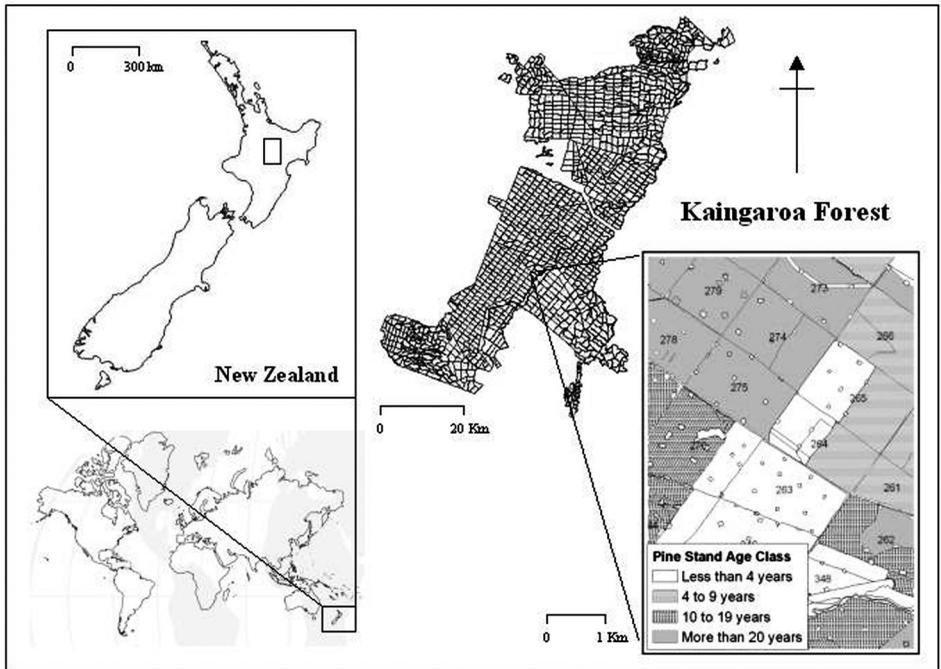
the distance and timing of natal dispersal include parental aggression (Lawrence & Gay 1991; Nilsson 1990), prey density (Kenward et al. 1993b; Nilsson 1989), food provision (Davies 1978), brood size (Kenward et al. 1993a), weather (Wiens et al. 2006), population density (Newton & Marquiss 1983) and physical and behavioural development (Kenward et al. 1993b).

The New Zealand falcon (*Falco novaeseelandiae*) is classified as threatened by the New Zealand Department of Conservation (Hitchmough et al. 2007). Describing dispersal is important if we are to understand the dispersion of a species in the landscape and how to best manage a species to ensure its conservation. Yet, few studies have examined dispersal of the New Zealand falcon (Barea 1995; Fitzgerald 1965; Lawrence & Gay 1991). Traditionally, New Zealand falcons breed in a range

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Fig. 1 Kaingaroa pine plantation and its location in New Zealand.



of habitat types, varying from rough pasture and tussock lands to beech and podocarp forests (Fox 1977). Recently, they have also been discovered breeding in exotic pine plantations (Addison et al. 2006; Stewart & Hyde 2004). In this study, we document the natal dispersal of New Zealand falcons in a pine plantation using radio-tagged and colour banded birds.

METHODS

The study was conducted in the Central Plateau of the North I of New Zealand, in the Kaingaroa Forest (Fig.1). Kaingaroa Forest comprises a single, 180,000 ha radiata pine (*Pinus radiata*) plantation. This is bordered to the east and west by native podocarp forest and dairy farmland, respectively, whilst the northeast and southwest boundaries of the study area were further areas of pine forest.

We documented the natal dispersal of New Zealand falcon fledglings by both tracking radio-tagged chicks from their nest sites and relocating colour banded fledglings in their eventual breeding territories. Backpack harnesses or tail mounts (Kenward 2001) were used to attach 22 radio transmitters to 22 falcon fledglings so they could be tracked to their breeding grounds. During the first 91 days from fledgling, individuals were located on a weekly basis. Thereafter their position was plotted once a month until the following breeding season. During the early stages of dispersal, fledgling falcons were located by driving to suitable vantage points and recording observations and/or triangulations using

a hand held yagi aerial and TR4 Telonics receiver. Subsequently, a car mounted omni directional aerial was used in conjunction with a hand held yagi to enable more efficient searching. At the start of the 2005 breeding season, fledglings that could not be located on the ground were followed up with an aerial search by flying 1 km transects over Kaingaroa Forest using a scanning receiver and 2 yagi aerials mounted to a Micro-light aircraft.

Nest surveys were undertaken during 3 consecutive breeding seasons, Sep to Mar 2003 to 2006, in an attempt to locate all falcon nests within Kaingaroa Forest. Potential falcon nesting habitat was identified from previous records of nesting falcon from Wingspan Birds of Prey Trust, the Raptor Association of New Zealand, the New Zealand Department of Conservation and several forestry companies. From these records, compartments containing pine trees aged less than 4 years old were identified as the most suitable for nesting. Compartments were surveyed on foot to solicit defensive behaviour, and listen and watch for other characteristic breeding behaviour. Forestry workers were also encouraged to report sightings of falcons. All of the fledglings from nests located during the first 2 breeding seasons were colour banded in order to identify individuals in subsequent breeding seasons. Fledglings were either banded on the nest or trapped after 50 days (before this time fledglings were not interested in the traps) with a balchatri or dho gaza trap (Bloom 1987). In addition to the chicks we banded, Wingspan Birds of Prey Trust and the

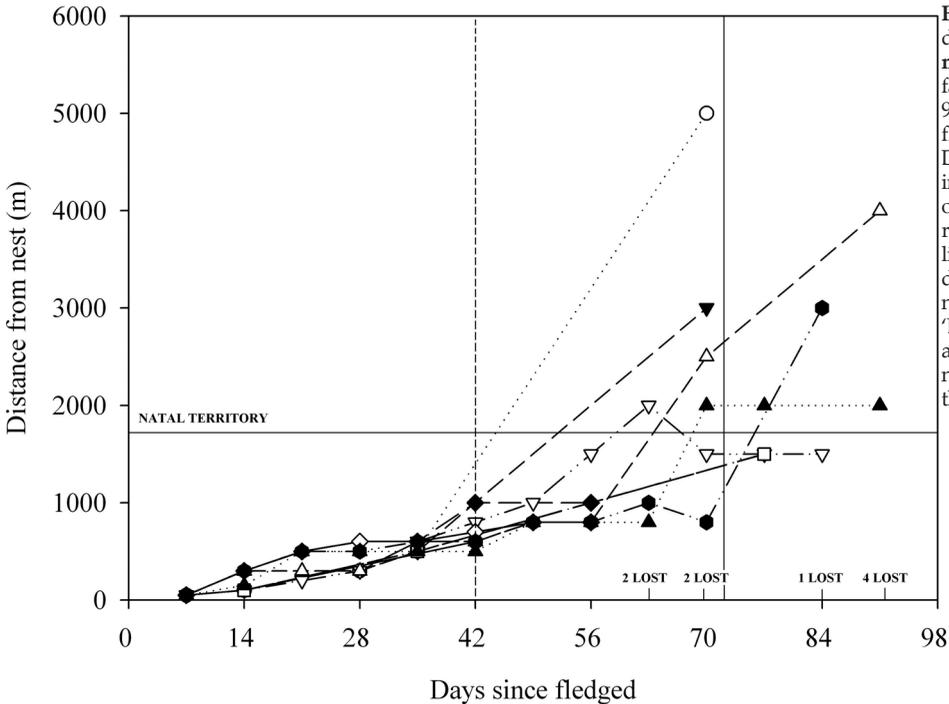


Fig. 2 Weekly dispersal distances of **male** New Zealand falcons during the 91 day period after fledging ($n = 11$). Dotted vertical line: initiation of dispersal out of the natal home range. Solid vertical line: mean timing of dispersal out of the natal home range. 'Lost' indicates that an individual could not be located after that time.

Raptor Association of New Zealand had banded 20 falcon chicks in Kaingaroa Forest since 1997.

Natal dispersal was considered initiated once a fledgling had moved more than 1.7 km from their nest site. This placed them outside of the 9 km² mean adult male falcon home range recorded in Kaingaroa Forest (Seaton *et al.* 2007a), effectively making them independent of their parents (Newton & Marquiss 1983). The difference in the initiation of natal dispersal between male and female falcons was assessed using a paired *t*-test.

Each year the colour bands of individual birds were noted in order to determine their age and the distance moved from their natal site. Natal sites and breeding territories were plotted in the GIS system, ArcMap 9.0, and the distance between them was measured in a straight line. The differences in natal dispersal distance and age of 1st breeding between males and females were assessed using Kolmogorov-Smirnov 2 sample tests. Pairs that did not attempt to breed were included in the analyses if they were observed together within the same compartment all season.

RESULTS

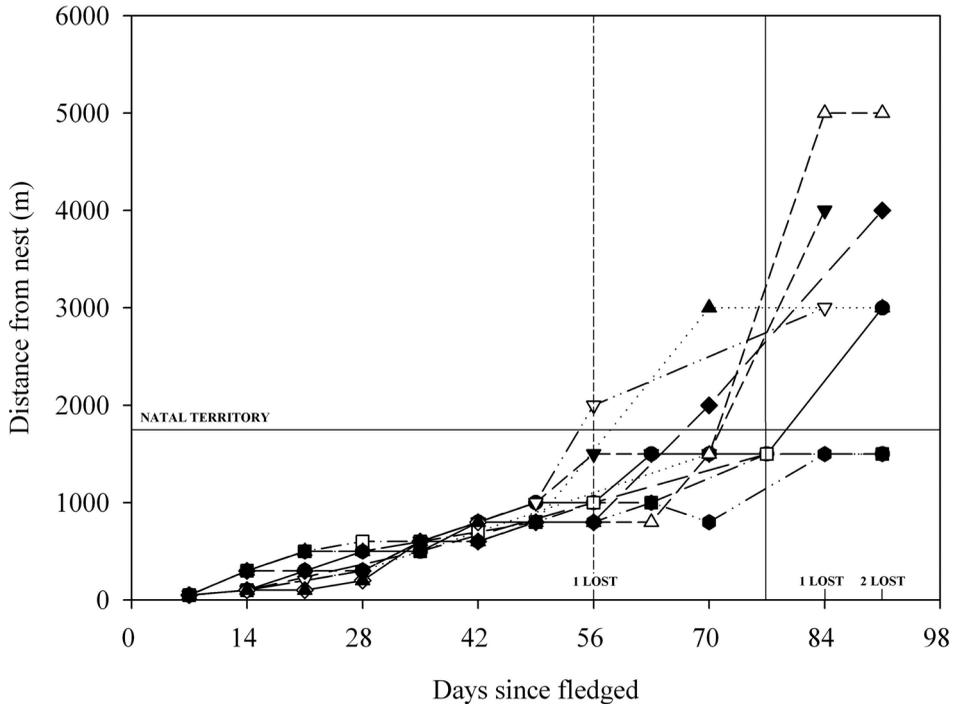
Eleven male and 11 female New Zealand falcon fledglings were fitted with radio transmitters and tracked for 91 days. Eighty-four breeding pairs were located in Kaingaroa Forest during the 2003 to 2005 breeding seasons. From these nests and those

previously located by Wingspan Birds of Prey Trust and the Raptor Association of New Zealand, 112 fledglings were colour banded.

Falcon fledglings dispersed out of their natal home range an average of 76 days after fledging. The mean onset of natal dispersal differed between males (74 days) (Fig. 2) and females (77 days) (Fig. 3), but this was not significant ($t = -0.96$, *d.f.* 8, $P = 0.18$). However, the 1st males began natal dispersal 42 days after fledging (Fig. 2) and the 1st females 56 days after fledging (Fig. 3). After 91 days, 91% of males and 82% of females had dispersed out of the natal home range. Four females and 9 males could not be located in Kaingaroa Forest after 91 days. One female did not disperse out of the natal home range and remained to breed there the following breeding season. One male died 91 days after fledging (cause unknown), without dispersing.

Of those fledglings tracked for the initial 91 day period, 11 were fitted with transmitters with a 12 month life span. We attempted to radio track these 6 males and 5 females through to the following breeding season. We successfully tracked 3 fledgling females through this period but no fledgling males. We were only able to track these 3 females because they remained relatively close to their natal sites, dispersing less than 4 km (Table 1). We were not able to follow the natal dispersal of any other fledglings through this period due to the large distances over which they dispersed and

Fig. 3 Weekly dispersal distances of female New Zealand falcons during the 91 day period after fledging ($n = 11$). Dotted vertical line: initiation of dispersal out of the natal home range. Solid vertical line: mean timing of dispersal out of the natal home range. 'Lost' indicates that an individual could not be located after that time.



the low intensity tracking technique employed. We therefore changed our searching technique and attempted to locate lost individuals by an aerial search the following breeding season. One female was located breeding 11.3 km away from her natal site. All other radio-tagged fledglings could not be located and were assumed to have left Kaingaroa Forest.

Of the 112 colour banded fledglings, 13 females and 5 males, were relocated in Kaingaroa Forest in subsequent breeding seasons. Of those relocated, the mean natal dispersal distance was 9.6 km, 8.7 km for females and 10.5 km for males (Table 1). Within Kaingaroa Forest, distances dispersed by male falcons ranged from 4.9 to 16.7 km, and 1.6 to 34.8 km for females. Natal dispersal distances did not differ significantly between the sexes (Kolmogorov-Smirnov two-sample test $K=0.63$, n.s.). For several individuals the natal dispersal distance could not be ascertained because we could not be certain that they did not breed in a year prior to 1st locating them. However, if the movement of pairs between nest attempts can be assumed to be minimal, which is the case in many other raptor species (Newton & Marquiss 1983; Wiens et al. 2006), then the distance to any nesting attempt (irrespective of age) may be regarded as similar to the natal dispersal distance. Including these individuals changes the mean dispersal distances to 12.4 km for females and 10.6 km for males.

Several females were recorded breeding successfully in their 1st year, whereas no males were recorded breeding successfully until their 2nd year (Table 1). The mean age of the 1st breeding attempt of females was 1.6 years, while males on average did not breed until 2.5 years (Table 1). This difference was not significant ($K>1.17$, $P=0.20$).

DISCUSSION

The age at which New Zealand falcon fledglings dispersed was highly variable among individuals. Nevertheless, previous studies of dispersal in New Zealand falcon suggest that dispersal may be initiated later in indigenous forest (Barea 1995; Lawrence & Gay 1991). This may be the result of lower bird densities. Compared with indigenous forests, pine plantations have higher densities of the birds on which falcons feed (Clout & Gaze 1984). Thus, falcons fledging in pine plantations may develop hunting skills more rapidly (Newton & Marquiss 1983), resulting in earlier independence and dispersal.

Male goshawks disperse earlier than females as a result of their smaller size, allowing earlier physical and behavioural development (Kenward et al. 1993a). This may be expected to occur in other raptor species with strong sexual dimorphism, although for New Zealand falcons we recorded no significant difference in the onset of dispersal between the sexes. Nevertheless, the mean onset

Table 1 Natal dispersal distances of New Zealand falcons, the age they were first located in a pair, and the age that they first attempted to breed. Mean values for each sex given in italics at bottom of columns.

Sex	Season fledged	Season relocated	Age of first breeding attempt (years)	Natal dispersal distance ¹ (km)	Age first located	Natal dispersal distance ² (km)
Female	1997/1998	2003/2004	Unknown	Unknown	6	27.91
	2000/2001	2003/2004	Unknown	Unknown	3	10.00
	2001/2002	2003/2004	Unknown	Unknown	2	9.57
	2002/2003	2003/2004	Unknown	Unknown	1	34.82
	2001/2002	2004/2005	3	5.85	2	5.85
	2002/2003	2004/2005	1	23.24	1	23.24
	2002/2003	2004/2005	2	3.80	1	3.80
	2002/2003	2004/2005	2	4.90	1	4.90
	2001/2002	2005/2006	2	1.59	2	1.59
	2002/2003	2005/2006	1	11.36	1	11.36
	2002/2003	2005/2006	1	9.20	1	9.20
	2002/2003	2005/2006	1	9.55	1	9.55
	2002/2003	2005/2006	Unknown	Unknown	1	9.84
		<i>Mean</i>		<i>1.6</i>	<i>8.69</i>	
Male	2001/2002	2004/2005	Unknown	14.05	2	14.05
	1999/2000	2005/2006	Unknown	Unknown	4	4.89
	2000/2001	2005/2006	3	9.75	3	9.75
	2001/2002	2005/2006	2	7.56	2	7.56
	2001/2002	2005/2006	Unknown	Unknown	2	16.65
		<i>Mean</i>		<i>2.5</i>	<i>10.45</i>	

¹Natal dispersal distances of individual falcons first breeding attempts

²Natal dispersal distances of individual falcons to the nest they were first located breeding, irrespective of whether they had possibly bred in another location in previous years

of dispersal was slightly earlier for males; the earliest individuals to disperse were male; a greater proportion of males had dispersed 91 days after fledging; and more males could not be located in the study area after 91 days. Therefore, although there is variation among individuals, there is a strong suggestion that males generally disperse earlier than females.

Radio telemetry and colour band recovery data indicate high emigration out of the study site. As a result, the dispersal distances of New Zealand falcons could not be fully described. The high emigration rates, however, indicate that the high densities of breeding falcons located in pine forests (Addison *et al.* 2006; Seaton *et al.* 2007b) could potentially supplement falcon populations in surrounding areas where they are in decline (Gaze & Hutzler 2004).

Many raptor species, including European sparrowhawks (*Accipiter nisus*), northern goshawk (*Accipiter gentilis*) and peregrine falcon (*Falco peregrinus*) show sex related differences in natal dispersal distances (Bechard *et al.* 2006; Newton & Marquiss 1983; Restani & Mattox 2000). Yet of those New Zealand falcons remaining within the study site, we found no significant difference between the sexes in dispersal distance. However, many more females were relocated breeding within the study site than males and more radio-tagged males dispersed out of Kaingaroa Forest. Although the data are not strong enough to support male biased dispersal it does seem that males are more likely than females to roam further afield during the transitional period between natal and breeding territories.

Several female falcons were recorded breeding successfully in their 1st year, a year earlier than in other habitats (Seaton & Hyde 2007). Earlier than usual breeding in other species of raptor is related to particularly favourable breeding conditions (Newton 1979). The early breeding in Kaingaroa Forest indicates that conditions in the pine forests were more favourable than in the more traditional forest and open hill country habitats of New Zealand falcon.

We conclude that the large proportion of individuals dispersing out of Kaingaroa Forest and the favourable breeding conditions afforded in this habitat indicates that New Zealand falcons in pine plantations are likely to act as source populations for neighbouring areas where falcons are in decline. We suggest that more long-term banding studies be carried out and that more intensive radio tracking or remote tracking methods be employed to more accurately describe natal dispersal and recruitment.

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