Sap feeding behaviour of North Island kaka (*Nestor meridionalis septentrionalis*, Lorenz 1896) in plantation forests

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Abstract

North Island kaka (*Nestor meridionalis septentrionalis*) damage plantation pines (*Pinus radiata* and *Pseudotsuga menziesii*) in the Whirinaki Forest. Kaka strip pieces of bark off the trunks to gain access to the sap beneath. Three methods were used to investigate this behaviour. Firstly, the Whirinaki and Kaingaroa Plantation Forests were surveyed to investigate the current levels of damage and the physical characteristics and location of damaged trees. Secondly, the movements and habitat use of kaka were investigated by radiotracking. Finally, the diet of kaka was determined, through direct observation, and seasonal changes in diet and damage frequency were documented.

The highest level of damage in a sampled compartment was 40% of surveyed trees (n=100), but 78% of the damaged trees had only 1-2 damage patches. Why some trees were damaged but not others was not determined because there was no relationship between damage and diameter at breast height (DBH), or tree position relative to topographical features. Kaka damage occurred up to 1km from the native forest. Trees suffering from crown dieback were no more likely to have damage than trees without dieback. At least 56% of trees suffering from crown dieback (n=144) in the surveyed compartments were not damaged by kaka.

The average core home range size for kaka, over 1 year, in dense podocarp forest was 15.5ha (n=6). All home ranges were within 2km (flying distance) of the exotic forest.

Only one of these birds bark stripped in the exotic forest, where it spent up to 97% of its time during September and October. There was a large degree of overlap between home ranges, although there was less overlap in the specific use of this space. Monthly changes in activity centres occurred often over the course of the year, but birds typically returned to areas where they had been previously; the average change in the position of activity centres each month was 203m. One bird had a large expansion in its home range size in July when few food sources were available but it did not use the exotic forest. This coincided with a time when there was a low level of damage in the exotic forest.

Four categories of food accounted for all of the feeding observations of kaka (n=2628): berries (24.3%), sap (24.0%), seeds (29.8%) and insects (22.0%). Eleven different tree species were used for food, and two of these were exotics; exotics accounted for 21.8% of total feeding observations and 38% of all sap feeding observations (n=366). Three podocarp species accounted for more than 50% of total feeding observations but only 6.7% of sap feeding observations. Seasonal changes in diet were evident. Berries were eaten from January-June; insects from March-October; seeds February-March and September-November; and sap from September-November. Bark stripping occurred mainly from September-December, with Douglas fir used during September and October, and tawa from October-December. This may be associated with an increase in sap sugar levels at the start of spring.

Acknowledgments

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General Introduction

Kaka (*Nestor meridionalis*) are large (400-500g) forest parrots endemic to New Zealand (OSNZ 1990). They represent one of only two surviving species in the genus. The other species in the genus is New Zealand's mountain parrot, the kea (*N. notabilis*). There are two subspecies of kaka: the North Island kaka (*N. m. septentrionalis*) and the slightly more colourful South Island kaka (*N. m. meridionalis*; Oliver 1955, Falla *et al* 1975, Holdaway & Worthy 1993). Both subspecies exhibit the cryptic colouration that is typical of the birds of New Zealand that were historically preyed upon solely by avian predators. The sexes are similar, although the male has a slightly larger beak (Soper 1984). They are a long lived species with low adult mortality (Butler 1992).

Although North Island kaka, on the mainland, are now largely confined to large areas of mature native forest (Moynihan *et al* 1979, Bull *et al* 1985, Moon 1992), they were once widespread across the North Island (O'Donnell & Rasch 1991, Butler 1992). They are classified as 'threatened' by Bell (1986) and 'vulnerable' by Collar *et al* (1994) and have been fully protected by law since 1953. The decline in kaka numbers seems to be a result of several interacting factors, including habitat loss or degradation, hunting pressure, and predation by and competition with introduced animals (Oliver 1955, O'Donnell & Dilks 1986, Beggs & Wilson 1991, Innes & Hay 1991, Moorhouse 1991, O'Donnell & Rasch 1991). There is evidence to suggest that this decline is continuing on the North Island mainland due to predation and competition

(O'Donnell & Rasch 1991, Clout & Craig 1994). Like many other New Zealand species, kaka may be vulnerable because they lack prior exposure to predatory mammals (Lovegrove 1992); the effect of mammalian predators may be further accentuated by the kaka's habit of nesting in cavities (Moorhouse 1991, Lovegrove 1992). The primary cause of mortality in kaka was predation of eggs, nestlings, young fledglings and incubating females (Moorhouse 1991). Kaka nests and young on the mainland are vulnerable to rats, stoats and cats; nesting females have also been killed by stoats. Wasps and possums may also compete with kaka for food (Beggs & Wilson 1991, Moorhouse 1991, Butler 1992).

One of the last remaining North Island mainland populations of kaka occurs in the Whirinaki Forest Park (Moynihan 1979, O'Donnell & Dilks 1991, O'Donnell & Rasch 1991) which adjoins the Whirinaki and Kaingaroa Plantation Forests. The dense and medium-dense podocarp forests, in particular, seem to support higher densities of kaka than other forest types (Moynihan 1979, Moynihan *et al* 1979). Even here, there is evidence of a decline in the population size (St Paul 1977).

One of the main feeding techniques used by kaka is sap feeding (O'Donnell & Dilks 1989). Kaka have a specialised brush tongue (Garrod 1872, Oliver 1955, Kirk *et al* 1993) which they use to collect nectar and sap. Kaka have two distinct techniques for collecting sap from native trees (O'Donnell & Dilks 1989). The first is to tap small holes into the surface cambium and lick up the resulting exudate (trap-door feeding, described by O'Donnell & Dilks 1989). The second technique is to strip the bark off the tree in small pieces and lick the sap directly from the exposed surface (bark stripping; Holloway 1948, Insley 1993, Innes 1980, 1994). Bark stripping occurs regularly on both exotic and native trees in the Whirinaki area (pers obs). Kaka damage to plantation trees may result in suppressed tree growth, needle yellowing followed by needle loss and, eventually, the death of those parts of the tree that are above the damage (crown dieback; Insley 1993). This damage has caused a conflict of interest over the management of kaka between the Forestry Corporation, who have a mandate to manage the plantation forests primarily along commercial lines, and the Department of Conservation who are required to protect kaka as a threatened species. It has been suggested that competition for food with possums in the native forest could be one of the reasons why kaka feed on sap in plantations (Insley 1993, Innes 1994).

Gouging bark specifically to produce a flow of sap is rare among vertebrates, but has been recorded in some primates, marsupials, squirrels and woodpeckers (Oliver 1968, Rushmore 1969, Kinsey *et al* 1975, Coimbra-Filho & Mittermeier 1976, Ostrey & Nichols 1976, Smith 1982, Craig 1985, Kenward *et al* 1988). There are no records of any other parrot species (Psittaciformes) actively feeding on sap using this method. Sap is an important food source for South American marmosets (Kinsey *et al* 1975, Coimbra-Filho & Mittermeier 1976), and sapsuckers (*Sphyrapius sp.*) in North America (Oliver 1968, Rushmore 1969, Ostrey & Nichols 1976). The marsupial sugar glider (*Petaurus brevicepsi*) and yellow-bellied glider (*P. australis*) of Australia specialise in feeding on exudates from *Acacia* and *Eucalyptus* trees (Smith 1982, Craig 1985). Grey squirrels (*Sciurus carolinensis*) actively strip bark and eat the phloem in beech and sycamore plantations; the heaviest damage occurs on trees with the widest phloem layer (Kenward *et al* 1988). Sap feeding behaviour in these groups has many parallels with

This thesis is written so that chapters have a similar format to journal papers and therefore some repetition occurs, especially in the ‘methods’ section of each chapter.

Chapter 1. Distribution, quantity and characteristics of trees damaged by North Island kaka (*Nestor meridionalis septentrionalis)* in the Whirinaki and Kaingaroa Plantation Forests, New Zealand

INTRODUCTION

Kaka (*Nestor meridionalis)* damage to plantation conifers is widespread in New Zealand, with damage being reported at Whirinaki (Insley 1993), the West Coast of the South Island, Nelson, Great Barrier Island and Pureora (Innes 1994; D Woodcock, Department of Conservation, pers comm). In plantation forests, kaka damage has been recorded on Douglas fir (*Pseudotsuga menziesii*), radiata pine (*Pinus radiata*), *Pinus nigra, P. ponderosa, P. muricata, P. sylvestris, P. canariensis, P. contorta*, Californian redwood (*Sequoia sempervirens*), western red cedar (*Thuja plicata*), and *Eucalyptus delegatensis* (Innes 1994).

Kaka damage to radiata pine and Douglas fir may result in suppressed tree growth, needle yellowing followed by needle loss and, eventually, the death of those parts of the tree that are above the damage ("crown dieback"; Insley 1993). Insley (1993) estimated that kaka damage caused losses in tree value of up to 23-30% in affected compartments in the Whirinaki Forest, with 148ha of radiata pine and 248ha of Douglas fir thought to be damaged (Insley 1993).

By determining the actual distribution and extent of kaka damage (in particular, the level of kaka-induced crown dieback) it would be possible to quantify losses, allowing forest managers to determine the severity of the problem. These data could also give insights to kaka feeding behaviour and habitat utilisation.

Bark stripping is a natural feeding behaviour for kaka and occurs regularly on tawa (*Beilschmiedia tawa*), totara (*Podocarpus hallii*), matai (*Podocarpus spicatus*) (pers obs), and a number of other native species (Buller 1888, O'Donnell & Dilks 1989, O'Donnell 1993). Kaka strip bark, not to eat the bark itself, but to expose the wood surface. The birds then lick, or scrape, the sap that leaks out of the surrounding cambium from the surface (Innes 1980, O'Donnell & Dilks 1989). The birds will also lick sap directly from the cambial surface of the bark piece (pers obs).

The damage kaka cause to plantation trees is easily characterised (Holloway 1948, Insley 1993, Innes 1980, 1994). Kaka strip small pieces of bark off the trunks creating distinctive wounds (Plate 1.1). The bark pieces (Plate 1.2) can often be seen scattered around the base of each tree. Each small piece of bark shows U-shaped dents or marks from the kaka's lower bill on its inner (cambial) surface and small holes on its outer (bark) surface from the sharp-tipped upper bill. The damage is largely confined to the trunk and tends to be located just above each whorl of branches. In some cases,

Plate 1.1 *Kaka damage on a Douglas fir tree.*

Plate 1.2 *Bark chips resulting from kaka damage to a Douglas fir tree. Note the U-shaped marks on the inner side of the bark chips, and the small puncture holes in the outer surface, from the kaka's bill.*

however, kaka damage has been observed on branches (pers obs). Most damage appears to occur on the upper third of the trunk.

There are still many aspects of bark stripping behaviour that are poorly understood, including why the damage occurs, when it occurs, which individuals are doing the damage, and why some trees are affected while their neighbours remain untouched. Some of these questions may be addressed by looking at geographical and physical differences between damaged and undamaged trees.

Beggs and Wilson (1987, 1991) concluded from their studies of kaka energetics that South Island kaka require foods with a high net energy return, in order to survive and reproduce. An analysis of honeydew (an important food source for kaka in South Island beech forests) showed that it contained fructose, sucrose, and glucose, along with small quantities of several oligosaccharides, in enough quantity to provide for the energy requirements of kaka (Grant & Beggs 1989). If North Island kaka also require these high energy foods, then sap could provide this when little nectar or fruit is available. radiata pine sap has high concentrations of soluble carbohydrates including glucose, fructose, sucrose, cyclitols, and quinic and shikimic acids (Cranswick *et al* 1987).

The objectives of this chapter were to:

1) determine, by examining tree characteristics, why some trees are more susceptible to damage than others;
2) map the distribution of damage within the exotic forest; and
3) quantify the extent of kaka damage within affected compartments.

METHODS

Study sites

This study primarily focussed on the Whirinaki Plantation Forest and those areas of the Kaingaroa Forest surrounding it. The Whirinaki Plantation Forest is in the Bay of Plenty, North Island, New Zealand. It is on the edge of the Kaingaroa Plateau and borders the Whirinaki Forest Park, a mainland stronghold for North Island kaka (Moynihan 1979, O'Donnell & Rasch 1991).

The Whirinaki Plantation Forest is a commercially managed forest containing a number of species exotic to New Zealand, with the majority of planting in the area being radiata pine and Douglas fir (Kaingaroa State Forest species distribution map, New Zealand Forest Service, Wellington, 1970)

Distribution of kaka damage

A computer search of the Forest Health Observers' (FHO) database (New Zealand Forest Research Institute, Rotorua) was conducted in October 1994, using the keyword "kaka". This database contained the results of all FHO surveys throughout New Zealand, from 1972 to 1994 (L Bulman, Forest Research Institute, pers comm). This search allowed me to determine in which forestry compartments observers had reported cases of kaka damage. Of these, ten were identified as heavily damaged by the FHO survey of kaka damage conducted in September 1993 (C Barr, Ministry of Forestry, pers comm).

Extent and characteristics of kaka damage

After establishing the distribution of kaka damage, I chose ten compartments to be surveyed in detail to characterise and quantify levels of kaka damage (Figure 1.1). The eastern edge of the Kaingaroa Forest adjacent to Whirinaki Forest Park was divided into three sections: northern, mid, and southern. The ten compartments were chosen from the three sections. The number of damaged compartments sampled in each area was proportional to the amount of damage that was recorded to occur there (FHO database 1994). Within each section, the compartments to be surveyed were randomly selected from those identified as containing kaka damage.

Sampled compartments (seven radiata pine and three Douglas fir) were surveyed by two people walking line transects. One person inspected the trees for kaka damage while the other measured and recorded tree characteristics. Transect lines were plotted on 1:10 000 scale maps of individual compartments, obtained from the Forestry Corporation (P O Box 1748, Rotorua). The lines were situated so that:

1) 50 trees could be surveyed in a straight line on a N-S axis and another 50 on an E-W axis;
2) the transects were easily accessible by foot; and

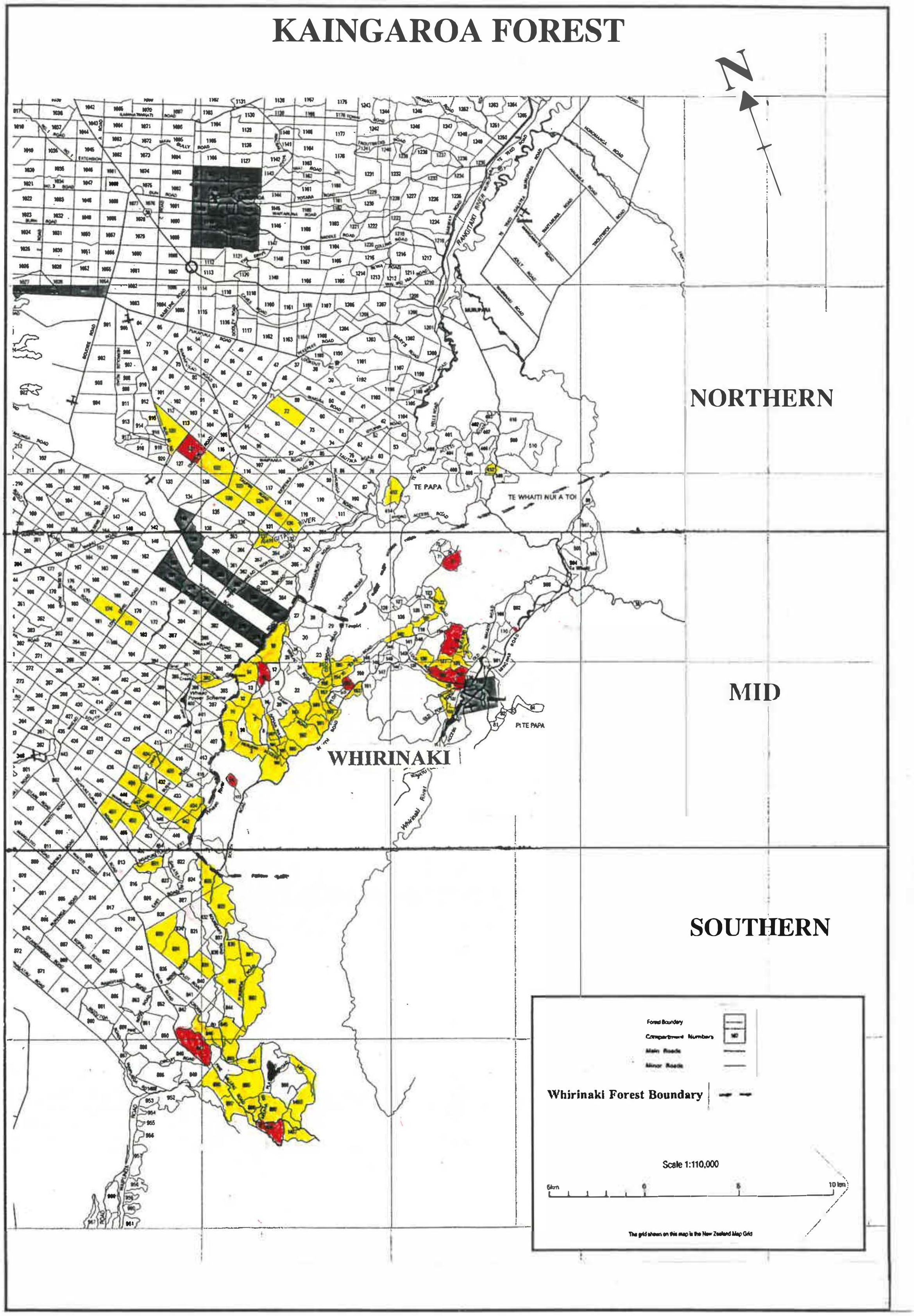


Figure 1.1 *Compartment map of the Whirinaki and Kaingaroa Plantation Forests. The coloured compartments are those identified as damaged from the FHO database. Red shows the location of the ten surveyed compartments. The clear spaces to the east of the forest boundary are predominantly native forest.*

3) the transects did not follow any particular geographical feature such as a ridge or gully.

Every 25 paces on the transect, a pair of trees was inspected with binoculars (Pentax $12x5^{O}$). One hundred trees from each compartment were inspected; this approximately accounted for less than 1% of trees within each compartment. The method used was similar to that used by Saunders (1974), McInnes and Carne (1978), Innes (1980), and Kenward *et al* (1988) to assess animal damage to trees.

The trees were inspected from at least three aspects, from as far back as possible without the view being restricted. Any kaka damage was noted, as well as the following tree characteristics: species, age, diameter at breast height (DBH), physiography (ie ridge, slope, gully or flat) and distance from compartment edge. The criteria for identification were that the scar was of a rectangular shape and located near a perch (ie above a branch whorl or on a branch). The presence of bark chips on the ground also assisted in identification. Any other damage was also noted. Often the cause of this damage could not be determined but possible candidates include high winds, rubbing against other trees, or possums.

If a tree was damaged, the number of damage patches and the height of the lowest patch relative to the tree height were also recorded. The number of those patches that were 'new' (ie they still had a bright yellow colour) and the number of 'old' patches (ie they were grey or black) were recorded as well as whether the patches had combined to ring-bark the tree. The presence/absence of crown dieback, a possible result of severe

RESULTS

Distribution of kaka damage

Compartments identified as containing kaka damage from the FHO database are shown in Figure 1.1; 87 compartments were identified as containing some level of kaka damage. Damaged compartments appear to be concentrated around the Whirinaki Forest and the south-eastern edge of the Kaingaroa Forest, with only a few scattered areas north of the Whirinaki Forest.

Characteristics of kaka-damaged trees

There was no significant relationship between the number of damage patches and DBH (Figure 1.2). Damaged trees did not differ significantly in their DBH from undamaged trees between compartments or even between species ($X^2 < 2.706$, df=1, NS).

Not only was the number of trees damaged by kaka equal across all physiographic types (Table 1.1; $X^2 < 2.706$, df=1, NS), but the amount of kaka damage was evenly distributed away from the native forest edge to approximately 1km into the exotic forest. This was true for the proportion of trees damaged as the distance increased (Figure 1.3; $X^2 < 2.706$, df=1, NS) and for the number of damage patches sustained by each tree (Figure 1.4; $X^2 < 2.706$, df=1, NS). Further observations incurred during monthly damage surveys and radiotracking (Chapters 2 & 3), suggested that both facets of kaka damage did occur at a higher frequency within 50m of the native forest edge. The initial survey technique did not pick this up because only a low number of trees were sampled this close to the edge.

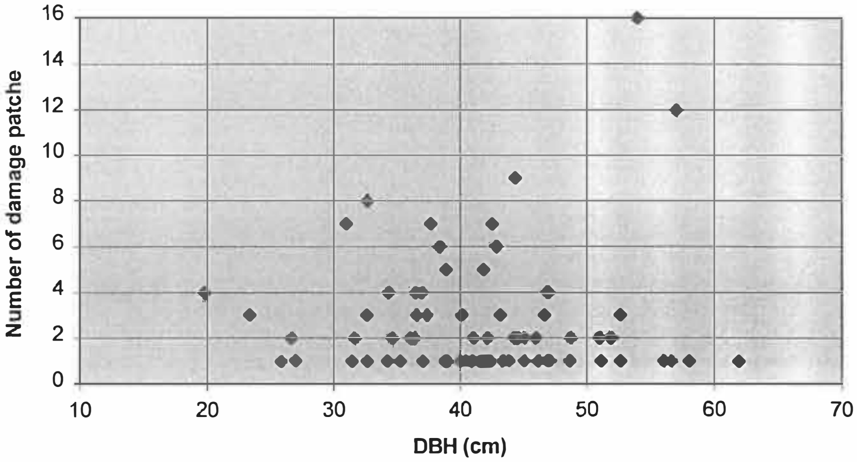


Figure 1.2 *Comparison of tree diameter (DBH) and the number of damage patches due to kaka.*

Table 1.1 *Percentage of trees damaged by kaka and total number of trees surveyed in each physiographical situation.*

Physiography	**Total no. trees**	**% of total**	**No. trees damaged by kaka**	**% damaged**
Ridge	26	2.6	2	7.7
Slope	302	30.6	28	9.3
Gully	110	11.1	11	10
Flat	550	55.7	34	6.2
All types	**988**	**100**	**75**	**7.5**

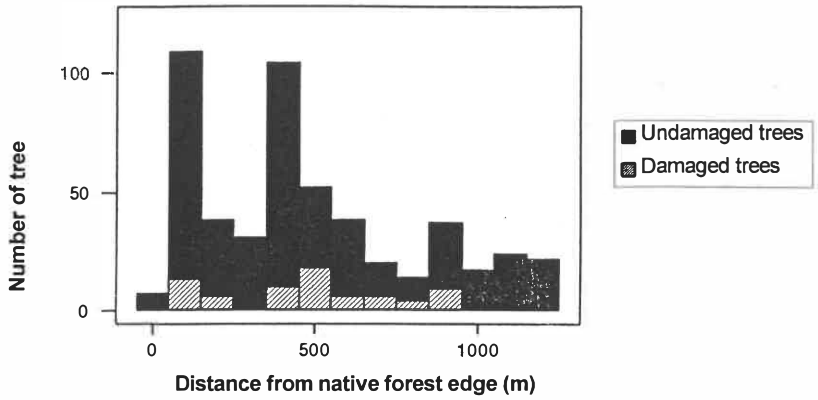


Figure 1.3 *Comparison of the distances of both kaka-damaged and undamaged trees away from the native forest edge.*

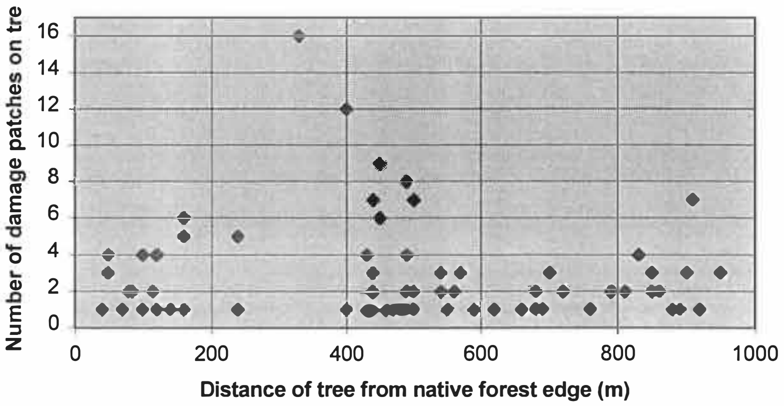


Figure 1.4 *Comparison of the number of patches of kaka damage on a tree and the distance of that tree from the native forest edge.*

The maximum distance surveyed from the native forest edge was 4km. All compartments identified from the survey as containing kaka damage were less than 1km from the native forest, except for compartment #153 which was exactly 1km away (Figure 1.5). Compartment #153 had the lowest frequency of kaka damage (1%) of the six kaka damaged compartments.

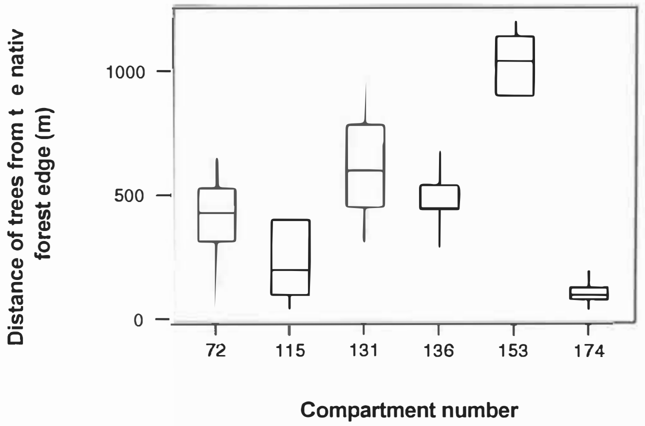


Figure 1.5 *Mean distance from the native forest edge of sampled trees in each damaged compartment. The bars show the standard deviation, while the vertical lines show the range.*

The distribution of the damage patches on the trees was easily characterised. Of the kaka-damaged trees surveyed, 76% had all their damage restricted to the upper 40% of the trunk. The lowest of any recorded damage patch occurred about a third (30%) of the way up the trunk (Figure 1.6).

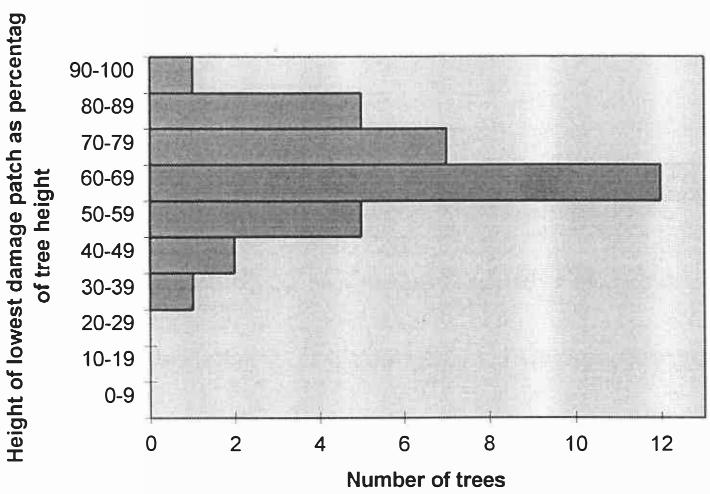


Figure 1.6 *The height of the lowest kaka damage on a tree. Heights are expressed as a percentage of tree height since all trees were of a similar height.*

The majority (67%) of kaka-damaged trees (n=75) had only 1-2 damage patches (Figure 1.7), with only a few (15%) having five or more patches. The maximum recorded number of patches on one tree during the survey was 16, but some trees were observed during the course of the study with over 30 patches.

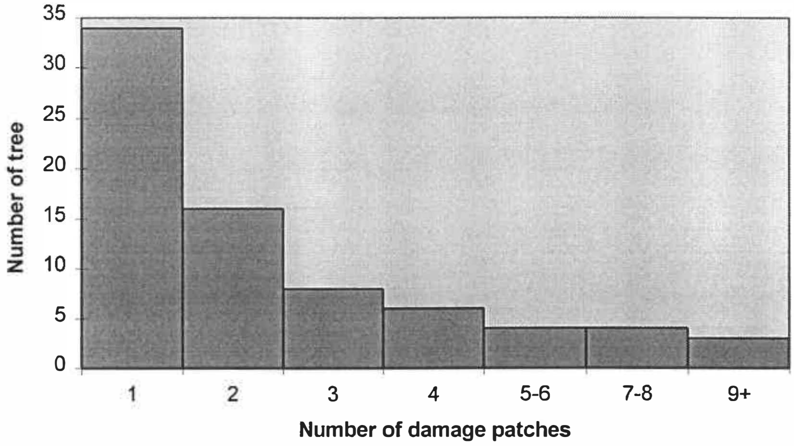


Figure 1.7 *Numbers of surveyed radiata pine and Douglas fir trees and incidence of damage patches present on their trunks.*

Extent of kaka damage

Not all of the compartments identified as damaged in the FHO database were found to contain damage by kaka in my survey (Figure 1.8). Of the ten compartments surveyed, four showed no sign of kaka damage at all and one of the remaining compartments had only a 1% kaka damage level (Figure 1.8). This suggests that kaka damage was either absent, at a relatively low level, or localised for these compartments. The highest level of kaka damage (40%) was detected in compartment #131, although a large proportion of the trees in this compartment had only one damage patch (Figure 1.8). In other compartments, the number of trees damaged by kaka ranged from 5-11% (Figure 1.8). There was very little difference between tree species. The amount of kaka damage sustained seemed to rely entirely on location, as only those compartments surveyed in the Whirinaki Forest showed any sign of kaka damage (see Figures 1.1 and 1.8).

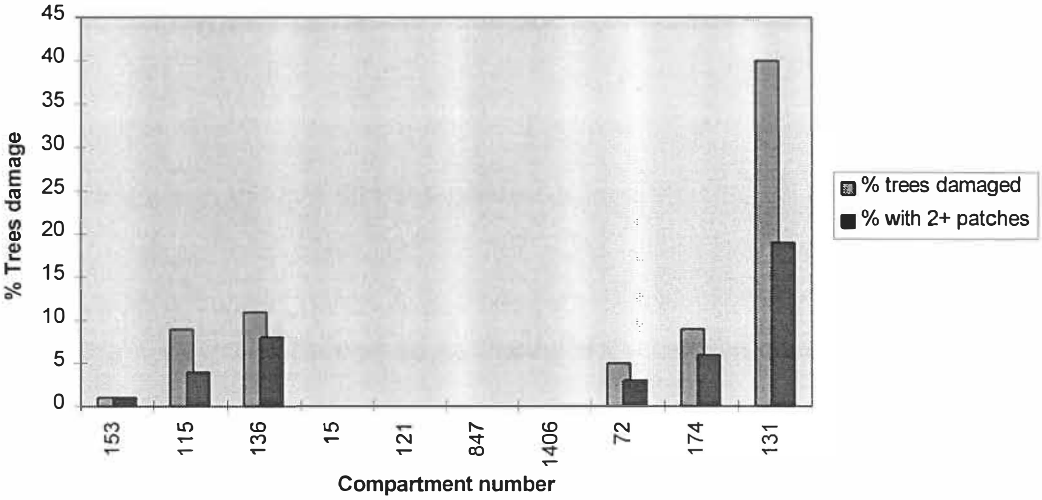


Figure 1.8 *Proportion of damaged trees in the surveyed compartments which have bark damage due to kaka. Compartments #121, #847 and #1406 are in the Kaingaroa forest, all others in the Whirinaki.*

The level of crown dieback recorded throughout the surveyed compartments was very low (Table 1.2). The compartment with the highest number of trees recorded with crown dieback was #1406, a compartment in which I located no kaka damage (Table 1.2). In fact, crown dieback trees were no more likely to have kaka damage present than non-dieback trees (X^2=2.077, df=1, p=0.150).

Table 1.2 *Species and proportion of trees suffering from crown dieback (CD) in each of the ten compartments surveyed.*

Compartment number	Species	No. trees sampled	No. showing crown dieback	No. of CD trees with kaka damage
153	*Ps. menziesii*	100	0	0
115	*Ps. menziesii*	100	1	1
136	*Ps. menziesii*	100	1	1
15	*P. radiata*	100	0	0
121	*P. radiata*	100	1	0
847	*P. radiata*	100	0	0
1406	*P. radiata*	100	19	0
72	*P. radiata*	100	1	1
174	*P. radiata*	100	1	0
131	*P. radiata*	100	3	1

Crown dieback survey

The proportion of trees observed to be damaged by kaka in the more detailed crown dieback survey, in compartments #131 and #72, was similar to that observed in the original/base survey (Figure 1.9). Trees suffering from crown dieback were no more likely to have kaka damage on them than any other tree ($X^2 < 2.706$, df=1, NS).

There were a number of trees (11%; 16 of 144 trees) for which the cause of the bark damage could not be determined, and it may not have been due to kaka. Even with these trees included, crown dieback trees were no more likely to have bark damage when compared to those with kaka damage from the original survey of these compartments ($X^2<2.706$, df=1, NS). Even if all observed damage was due to kaka, 56% of 100 trees with crown dieback were definitely not damaged by kaka in compartment #131, and 79% of 44 trees in compartment #72.

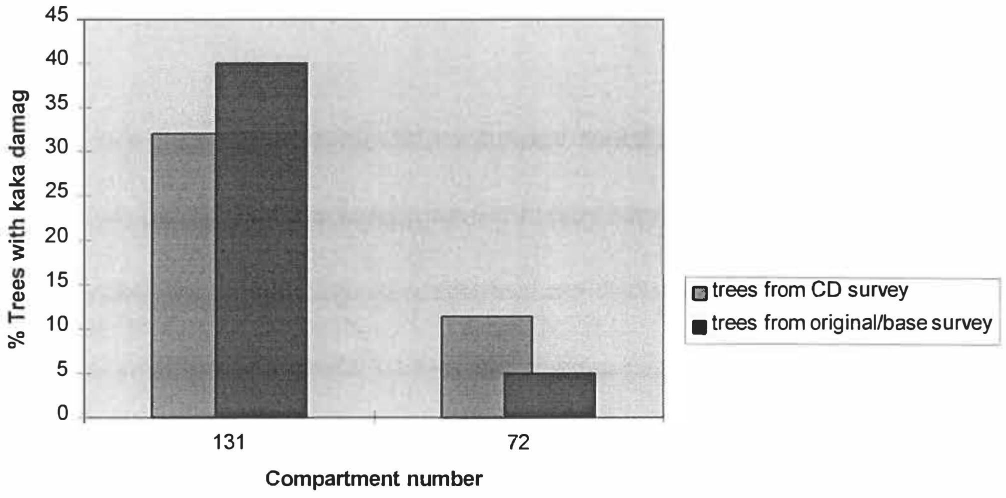


Figure 1.9 *The proportion of trees with kaka damage from the crown dieback survey compared to the original/base survey.*

DISCUSSION

Distribution of kaka damage

Nearly half of the ten surveyed compartments showed no signs of kaka damage (Figure 1.8), and those damaged by kaka were all within 1km of the indigenous podocarp forest. This suggests that kaka damage may be restricted to within 1km of the plantation forest edge. If this is the case, then the number of compartments showing signs of kaka damage may be less than the 87 identified from the FHO database as some of these are further than 1km (see Figure 1.1). Kaka seem to occur in highest densities in the moderate to dense podocarp stands of the Whirinaki Forest Park so damage may be particularly concentrated in this area (Moynihan 1979, Moynihan *et al* 1979).

Although my results are based upon a limited sample size, they suggest that the FHO database may sometimes be unreliable with regard to kaka damage; perhaps some FHO staff recorded crown dieback as kaka damage even if they did not observe damage patches. It does not appear that all of the FHO staff used the same criteria as I did to identify kaka damage and kaka induced dieback (C Barr, MOF, pers comm).

Characteristics of kaka damaged trees

A number of physical and locational characteristics of trees were examined in the present study but no relationship could be found between these and kaka damage. There was no relationship between DBH and damage, and no relationship between physiography and damage. Why a kaka selects a particular tree to feed on is, therefore, still unknown. The only relationship found had to do with the distance between trees and the native forest edge. Trees that were closer to the native forest were more susceptible to kaka damage. The role that a tree's height, relative to its neighbours, has in attracting kaka was not investigated, but could be an important factor, especially considering that kaka prefer emergent trees within the native forest (O'Donnell & Dilks 1994). Although plantation trees within each compartment are of equal age, some trees do grow more quickly and are slightly taller than the trees around them.

Other studies of animal damage to trees have also been unable to determine why particular trees are favoured targets for damage. Trees used for sap feeding by yellow-bellied gliders were no larger than other trees in the surrounding forest (Craig 1985) and the properties of individual eucalyptus trees which make them suitable as sap sites are not known (Smith 1982). O'Donnell and Dilks (1989) found that the DBH of rata (*Metrosideros umbellata*) trees did not influence their selection as sap feeding sites by South Island kaka. Other studies of sap feeding by sapsuckers, yellow-bellied gliders, and marmosets have also failed to find a relationship between damage and DBH (Oliver 1968, Coimbra-Filho & Mittermeier 1976, Smith & Russell 1982).

Kenward *et al* (1988) found that the trees most heavily damaged by grey squirrels were those with the widest phloem layer on their stems; squirrels were getting the greatest volume of phloem per unit area from these trees. This could be a determining characteristic for kaka damage, but further investigation will be required to confirm this.

Kaka damage appeared to be mainly in the upper half of trees. This is consistent with my observations of kaka feeding and those of O'Donnell and Dilks (1986, 1994), who found that kaka mainly used the upper levels of the native forest.

Extent of kaka damage

Based upon my limited sample size, kaka damage in the Whirinaki Forest may be at a lower level than previously suggested by Insley (1993) and the FHO database. Of the ten compartments surveyed, not only were fewer affected but the level of kaka damage within these compartments was generally lower than suggested by Insley (1993). Exceptions to this are the six compartments identified as damaged (FHO database, 1994) closest to the Tauranga Basin Ecological Area at the end of Old Fort Road. In the one compartment surveyed in this area (compartment #131), the proportion of kaka-damaged trees was reasonably high (up to 40%) but a large proportion of these (78%) had only 1-2 patches. The elevated damage levels in these compartments could be due to their close proximity to an area of dense podocarp forest which supports high numbers of kaka (Moynihan 1979, Moynihan *et al* 1979). In the other damaged compartments, 5-11% of the 100 trees surveyed in each compartment had kaka damage, which could reflect their increased distance from the podocarp forests.

Compartments that were reasonably close to native forest kaka habitat contained kaka damage, with the heaviest damage occurring within 50m of the native forest edge. Optimal Foraging Theory suggests that animals will seek to minimise energy expenditure when foraging (Stephens & Krebs 1986). Feeding close to the native forest edge will maximise energy gains for kaka living in the native forest by reducing the distance travelled by the bird from its activity centre to obtain food. It does not seem logical that birds would travel large distances from the native forest edge when the same food source occurs closer. Chaun (1969) found that porcupines would only attack oil palms in plantations within 80m of the forest boundary.

Kaka damage occurs high in the tree. Due to the density of the canopy, not all damage will have been seen and thus it is expected that this survey has underestimated the degree of damage. It was not practical to fell a large number of these trees to check the accuracy of this survey method. However, the degree of underestimation was probably not that high and, it will certainly not affect comparisons between surveyed compartments. Where crown dieback occurred in radiata pine the area immediately around the height of dieback was always visible.

Crown dieback

Although the number of trees recorded with crown dieback in the surveyed compartments was low (Table 1.2), the actual number of trees suffering crown dieback may be higher than these figures indicate. For example, in compartment #131 the proportion of trees suffering from crown dieback was initially recorded as 3% (Table 1.2) but data from the monthly damage surveys for this compartment suggest that the level of crown dieback was actually about 20% (Chapter 3), which brings these figures into line with previous estimates (Insley 1993). However, how much of this dieback is due to kaka damage?

The results show that trees with crown dieback were no more likely to have kaka damage than any other tree within the compartment (Figure 1.9). In fact, in the two compartments surveyed, over half of the trees showing signs of crown dieback had no bark damage at all (Figure 1.9). This suggests that kaka may not be responsible for at least half of the crown dieback occurring in plantation forests.

If it is accepted that approximately 10% (eg the level seen in compartments #131 and #72) of trees were suffering from crown dieback, then kaka may be damaging half of these, so approximately 5% of all of the trees in these two compartments could be suffering from kaka-induced dieback. It is worth noting that although this figure is for the total amount of kaka damage, it is only in certain circumstances that a small amount of damage will cause dieback (ie 1-2 patches) and then it is usually due to a combination of secondary factors such as wound pathogens, stress, water-logging, and drought (C Barr, MOF, pers comm). It has been suggested that a healthy, stress-free tree would need the entire circumference of the transport tissue removed to a depth of over 10cm before kaka damage alone would cause dieback (D Smith, Forest Research Insitute of New Zealand, pers comm). Therefore, the actual number of trees suffering dieback as a direct result of kaka damage may be lower than the number of trees with kaka damage.

If no secondary factors such as infection, drought or water-logging increase the susceptibility of the tree to dieback, then ring-barking of the tree by kaka may be required to initiate crown dieback (D Smith, pers comm). Of the trees with dieback I surveyed (n=144), 33% were ring-barked, but only 14% were ring-barked and had signs of kaka damage (eg a rectangular scar close to a perch). What caused the rest of the ring-barking is unknown, although at least half of it appeared to be due to bark flaking after tree death which could have obscurred old kaka damage. Therefore, 14-33% of the crown dieback in these two compartments may be due to kaka damage; this accounts for 1.4-3.3% of all of the trees.

It seems reasonable to assume that the true figure for kaka-induced dieback, in compartments #131 and #72, will be somewhere between the two extremes of 1.4-3.3% if ring-barking is required to kill the tree, and 5% if any level of kaka damage will kill. This accounts for 14-50% of all the trees suffering from crown dieback in these two compartments.

The question remains, if not kaka damage, then what is causing the majority of crown dieback? Other causes of crown dieback may include physical damage by possums, wind, snow and land subsidence, poor drainage, nutrient deficiency, Upper Mid-Crown Yellowing (UMCY) (Beets *et al* 1993), or pathogens such as *Diplodia pinea* (Chou 1984) and *Cyclaneusma minus* (Bulman 1993).

D. pinea is a fungal pathogen that infects *P. radiata*, *Ps. menziesii*, and a number of other species (Chou 1984). It infects woody stems usually, though not always, through wounds (Chou 1984). Kaka damage may increase the susceptibility of trees to crown dieback, due to *Diplodia*, by increasing the number of wounds on a tree. Although the factors favouring infection are unknown, stress is thought to be a contributing cause (Chou 1984).

The crown dieback survey focused only on kaka damage, and identifying other causes of crown dieback was beyond its scope, but cases of UMCY, *Cyclaneusma* (a needle pathogen), and *Diplodia*, as described by Chou (1984), Beets *et al* (1993) and Bulman (1993), were seen. Further study on the contribution of each of the above factors to the total level of crown dieback is required if a management plan to minimise crown dieback is to be devised.

Chapter 2. Home range of North Island kaka (*Nestor meridionalis septentrionalis*) and its association with sap feeding in the Whirinaki Forest, New Zealand

INTRODUCTION

Kaka (*Nestor meridionalis*) are large (400-500g), gregarious, arboreal parrots that are endemic to New Zealand (Soper 1984). There are two subspecies of kaka, one occurring in the North Island (*N. m. septentrionalis*) and the other in the South Island (*N. m. meridionalis*; Moon 1992). Both are classified as threatened (Bell 1986). on the mainland, the North Island sub-species only occurs in relatively high numbers at Whirinaki and Pureora (Moynihan 1979, Moynihan *et al* 1979, O'Donnell & Rasch 1991).

One of the feeding techniques used by kaka is sap feeding. This involves stripping bark off the trunks of trees in small strips and then licking the sugar-rich (Cranswick *et al* 1987) sap from both the exposed surface and the bark strips (Buller 1888, Innes 1980, Beggs 1988, O'Donnell & Dilks 1989, O'Donnell 1993). Damage from bark stripping is evident both on native trees in the Whirinaki Forest Park (Chapter 3), and in exotic trees in the neighbouring Whirinaki Plantation Forest (see Chapter 1). The damage to plantation trees may result in suppressed tree growth or even crown dieback (Insley 1993), causing some concern for forest managers. Although bark stripping is a common feeding technique (12% of feeding observations of kaka in Whirinaki involved bark stripping [Chapter 3] and 3% of the kaka's diet in South Westland was made up of sap [O'Donnell & Dilks 1994]), there is very little quantitative information on how and where it occurs. For example, it is not known whether only certain individuals of a population feed on exotics this way, where the birds come from or if the damage is seasonal.

A home range is defined as the area habitually used by an animal; that is, the area in which it spends most of its time (Drickamer & Vessey 1992). Seasonal shifts in the home range of North Island kaka, related to food supplies, may occur. Other studies have found kaka to be sequential, specialist feeders, moving from one particular food source to another as they became available (O'Donnell & Rasch 1991, O'Donnell & Dilks 1994). For example, in South Westland, kaka moved between altitudes or forest areas in different seasons (O'Donnell 1991). In August, they occupied areas above 600m to feed on rata sap (*Metrosideros sp.*), from October to December they fed on fuchsia (*Fuchsia excorticata*) nectar at low altitudes, and from December to January they fed on the nectar of southern rata (*Metrosideros umbellata*) and mistletoe (*Peraxilla sp*). In February, the birds were again found at lower altitudes, feeding on rimu (*Dacrydium cupressinum*) fruit until April and then rimu seeds until August.

Kaka are capable of covering large distances. Near Nelson, one juvenile moved 100km in a week (P R Wilson, Landcare Research, pers comm), and some females regularly covered distances of up to 20km a day (O'Donnell & Rasch 1991). As a result, one might expect home ranges to be large. In Nelson Lakes National Park, male kaka can have ranges of up to 1600ha (O'Donnell & Rasch 1991). At Pureora, in the North Island, home ranges appear to be much smaller. Of 19 birds radiotracked, the largest distance between position fixes was only 7km and these fixes were collected almost 6 months apart (T Greene, pers comm).

One way to better understand the mechanisms and implications of sap feeding behaviour is to study the kakas' home range. A study of kaka home ranges and local movement patterns would reveal information on:

1) the proportion of a kaka's time budget spent in the exotics and the amount of exotic forest included in their home range;
2) how far the birds travel to feed on the sap of plantation trees;
3) seasonal variation in the use of exotic forests;
4) whether feeding in exotics is a common activity amongst kaka;
5) how 1-4 (above) relate to food availability and the kaka's use of native forest.

By quantifying these features of kaka biology, I will provide valuable information for the development of a conservation strategy and data that will allow forestry managers to develop management plans and/or techniques to minimise damage to plantation trees.

METHODS

Study sites

The Whirinaki Forest forms a transition zone between the Kaingaroa Plateau in the West and the Urewera Ranges in the East (Field & Garratt 1979). It contains one of the largest areas of unlogged lowland podocarp forest left in New Zealand (Nicholls 1978).

Two study sites were used: the Fort Road area (38° 39'S: 176° 43'E Infomap 260 V18) and the Totara Salvage Road area (38° 41.5'S: 176° 35.5'E Infomap 260 V18; Figure 2.1). Both of these sites were within the Whirinaki State Forest, in areas of medium-to-dense podocarp forest with an extensive tawa understorey. The Fort Road site was situated immediately west of the Whirinaki River and was very close to a large area of exotic forest (Whirinaki Plantation Forest). This site was sampled from December 1994 until December 1995. The Totara Salvage Road site was located east of the Wheao River, close to the Taho and Waione Flats. This site was sampled from December 1994 through to August 1995.

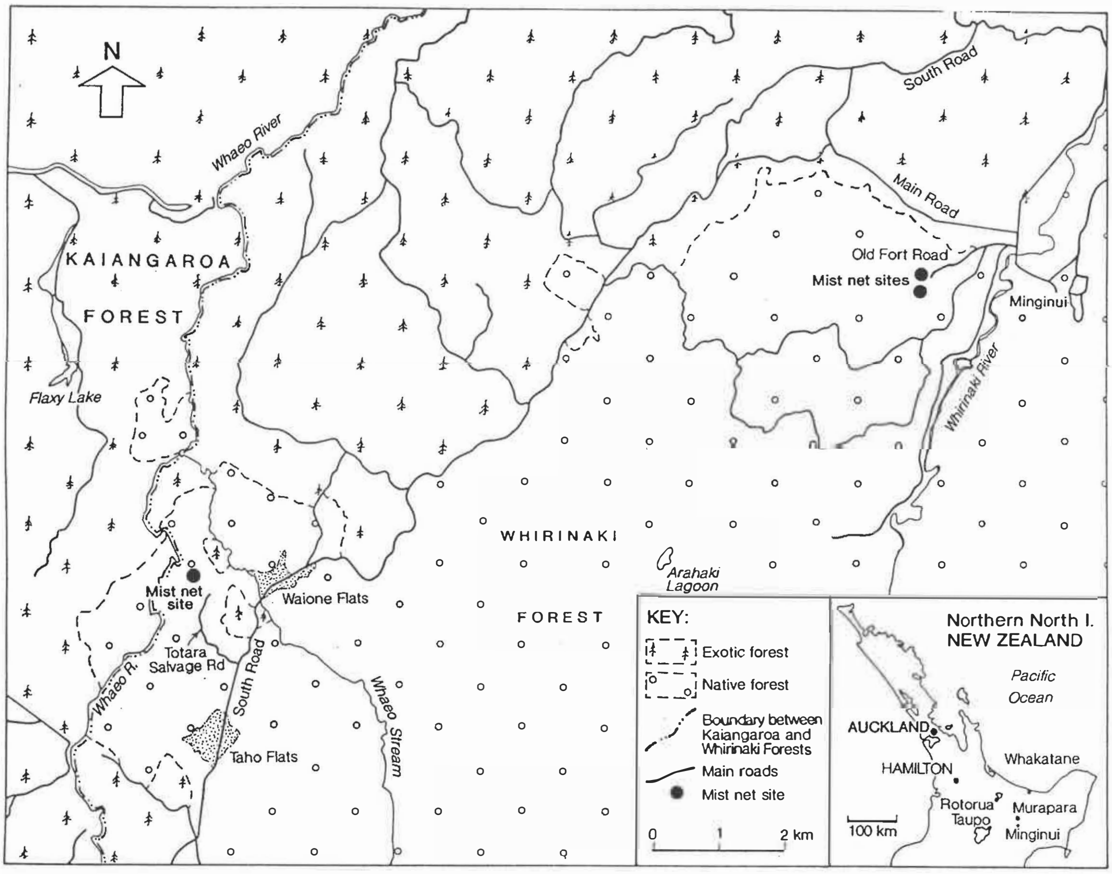


Figure 2.1 *Map of the Whirinaki area showing the location of both study sites.*

Trapping

Department of Conservation contractors were employed to capture kaka. They did so by errecting mist-nets. All equipment used belonged to the Department of Conservation.

Two mist-netting sessions were conducted during the study period. One session occurred in September 1994 and resulted in the attachment of functional transmitters on three birds (two at Fort Road and one at Totara Salvage Road). The other session occurred in September 1995 and resulted in another three birds carrying transmitters (all at Fort Road).

Mist-nets were 12.2x2.1 metres in size with a mesh diagonal measurement of 6.0cm. The height of mist-net sites ranged from 15m to 23m and a series of nets were linked together to cover this area. The mist-net sites are shown in Figure 2.1. The birds were lured into the nets by the playback of recorded kaka calls.

Once captured, the birds were measured and individually marked with "triple combination" coloured plastic bands and a metal band on the opposite foot. A radio-transmitter, weighing 19.8g (4-6% of bodyweight, heavier than the 2-3% recommended by Kenward 1987), was then attached to the bird's back using a harness with a weak link (see Karl & Clout 1987). The transmitters were Sirtrack two-stage units which operated on different frequencies in the 160 MHz waveband and emitted a pulsed signal.

After release, kaka appeared to adjust rapidly to carrying the transmitter packages, exhibiting normal behaviour alongside untagged individuals.

Study animals

Birds were sexed by their bill length. Those with a bill length over 47mm were considered male; those under, if not displaying juvenile characteristics (Moorhouse & Greene 1995), were considered female (Soper 1984, Beggs 1988).

The birds carrying transmitters from the 1994 mist-netting session were all adult males. Those from 1995 included two adult females and one adult male. The bill length and size of these birds is shown in Table 2.1.

Table 2.1 *Measurements from kaka that carried functional transmitters.*

Bird No.	Year Caught	Net Site	Sex	Weight (g)	Bill Length (mm)	Sampling Period	No. of Fixes
1	1994	Fort Rd #1	Male	480	49.6	Dec 94-June 95	86
2	1994	Fort Rd #1	Male	475	49.9	Dec 94-June 95	87
3	1995	Fort Rd #2	Female	500	43.0	Sept 95-Dec 95	40
4	1995	Fort Rd #2	Female	500	40.9	Sept 95-Dec 95	46
5	1995	Fort Rd #2	Male	325	48.1	Sept 95-Dec 95	40
6	1994	Totara Salvage Rd	Male	443	50.1	Dec 94-Aug 95	75

Home range data collection

Home range data were collected using a method that was similar to that of Barea (1995), Clout *et al* (1995), Joshi *et al* (1995) and Rolando *et al* (1995). Kaka were tracked from the ground using a Telonics TR-4 receiver and a directional 3-element Yagi aerial. Once a bird was located it was observed until it changed its perch tree. The position of that tree in relation to set, marked positions in the study area was then determined. Kaka were considered perched if they were standing on any object or on the ground. Perch use is a good measure of habitat use for feeding because all kaka feeding is done when perched.

As well as the position of the bird, the date, time spent at a given grid point, transmitter frequency, band combination, terrain, height of the bird and tree, main perch species, number of birds using that tree, bird's station, perch type and weather were also recorded. All observations were dictated into a voice recorder and later transcribed.

Calculation of home range

A major problem associated with the continuous monitoring of an animal is that while it reveals valuable biological information on an animal's lifestyle, observations of animal locations and movements can lack statistical independence. This can cause underestimates of home range sizes (Swihart & Slade 1985, McNay *et al* 1994).

However, since kaka are capable of traversing their home range in less time than the mean interval that occurred between my consecutive position fixes (55.7±45.3 minutes), the data I have collected can be considered independent (Swihart & Slade 1985).

Minimum Convex Polygon (90-100%) home ranges (MCP's) were generated to determine the size and shape of core ranges (Ranges IV software, Kenward [1990]). The core range presented (ie 90, 95, or 100%) was determined from habitat utilisation plots, with the point of greatest slope increase defining the limits of the core range (Kenward 1990).

By using core range MCPs, with the harmonic mean as a centre, I eliminated the disproportionate effects of outlying fixes on home range size (Nugent 1994) and minimized the negative effects associated with continuous sampling (Garshelis 1983, Lair 1987, Kenward 1990, Weavers 1993, Joshi *et al* 1995). The harmonic mean centre is a good estimate of true centre of activity (Dixon & Chapman 1980, Lair 1987).

RESULTS

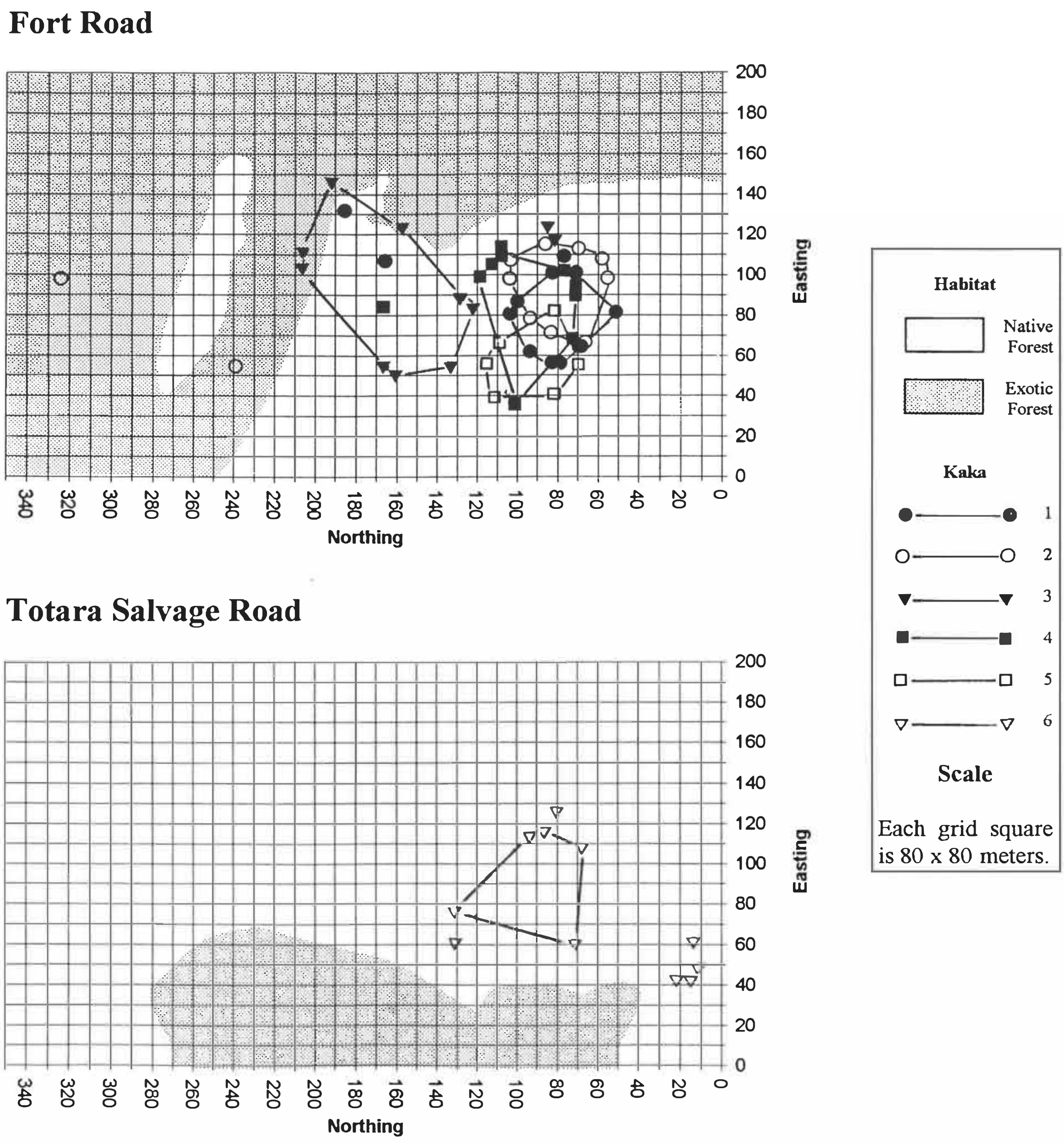
Home range of North Island kaka

The average core home range size for the six birds I studied was 15.5±7.5ha (Table 2.2). Bird 3's home range was 93% larger than the mean home range area. The other birds did not differ much in their home range sizes. The average home range size for these five birds was 12.7±2.9ha (Table 2.2). The harmonic mean for each bird was well separated from those of the other birds. The closest harmonic means were 176m apart (Table 2.2).

Table 2.2 *The core home range size and activity centre for each bird for the total study period.*

Bird number	% MCP of core range	Core range area (ha)	Position of harmonic mean on grid (East, North)
1	95	9.7	69, 78
2	95	15.1	108, 74
3	95	29.9	59, 164
4	95	15.3	68, 101
5	100	9.3	39, 99
6	90	13.9	81, 92

Bird 3 was the only bird that incorporated exotics within any part of its core home range, and this was less than 5% of its total core range area (Figure 2.2). Only one other bird (Bird 2) was seen to enter the exotic forest, and it travelled 2km from its harmonic mean centre of activity to do so (Figure 2.2). This bird was not observed to strip bark during this excursion.



Fort Road

Totara Salvage Road

Figure 2.2 *Core minimum convex polygon (MCP) home ranges and outliers for the entire study period for each kaka.*

There was a large degree of overlap between the core ranges of birds at the Fort Road site. Of the five birds at this location four had overlapping ranges (Figure 2.2). Only Bird 3 had no overlap with the other home ranges, but its area did incorporate the outlying fixes of two birds (Figure 2.2).

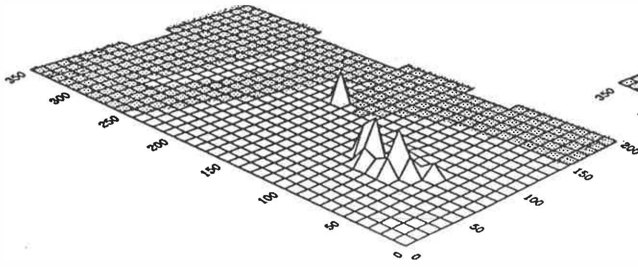
Kaka's use of home range area

Although a lot of overlap occurred in home range area (Figure 2.2), there was less overlap when I examined how many minutes each kaka was observed at each grid point over the study period (Figure 2.3). Each bird seemed to spend most of its time in areas that were slightly different to the ones used by the other birds, although most of them did spend at least some time in the same positions, occasionally at the same time (pers obs).

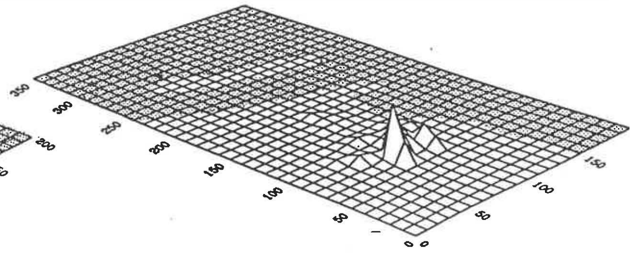
Once again it can be seen that five of the birds were observed to spend very little time in the exotic forest (Figure 2.3). Three of these birds spent time close (within 200m) to the native/exotic edge, but did not cross into the exotics during my observations. Generally, the birds remained quite localised throughout the year (Figure 2.3).

FORT ROAD

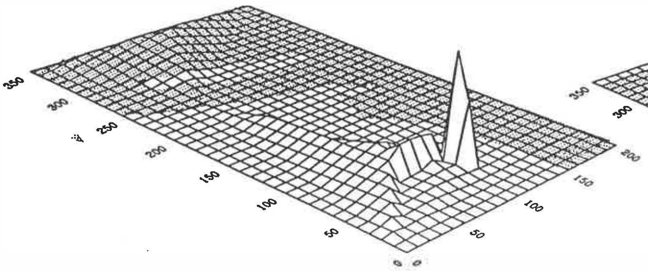
Kaka 1



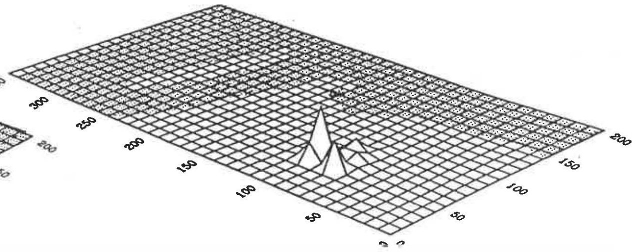
Kaka 4



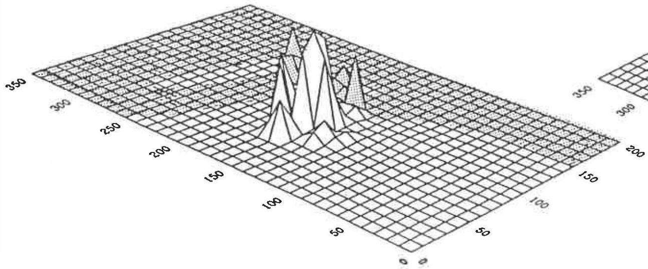
Kaka 2



Kaka 5



Kaka 3



TOTARA SALVAGE ROAD

Kaka 6

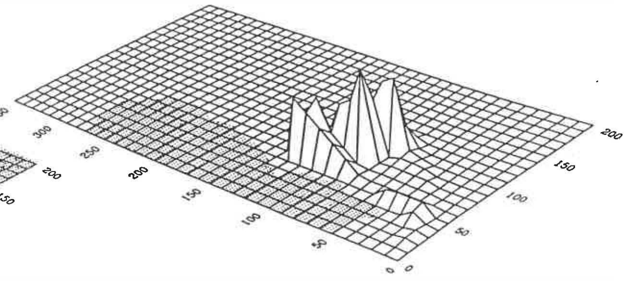


Figure 2.3 *The amount of time (in minutes) kaka were observed at each grid point in the habitats they occupied. The stippled area is exotic forest, the unshaded area is native.*

Seasonal changes in home range

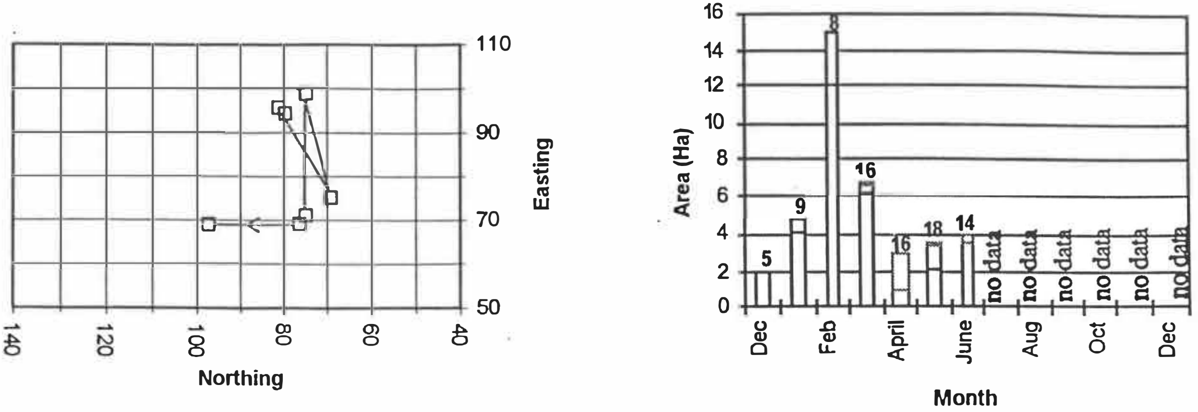
Incremental area analysis was initially used to determine when enough fixes had been gathered to qualify a home range. The plots for all the study birds reached an asymptote quickly but, with continued sampling, would then increase again and again until new asymptotes were reached. Therefore, I considered it inappropriate to use incremental area analysis to determine when I had gathered enough sample points but rather followed a regular monthly sampling regime.

Although the monthly centre of activity usually differed from month to month, quite substantially in some cases (up to 640m), the birds' areas of use were actually quite small. The centre of activity often returned over the course of three to four months to earlier positions (Figure 2.4). The average monthly change in the position of the centre of activity for all six birds was 208±170m, and the smallest change was 16m.

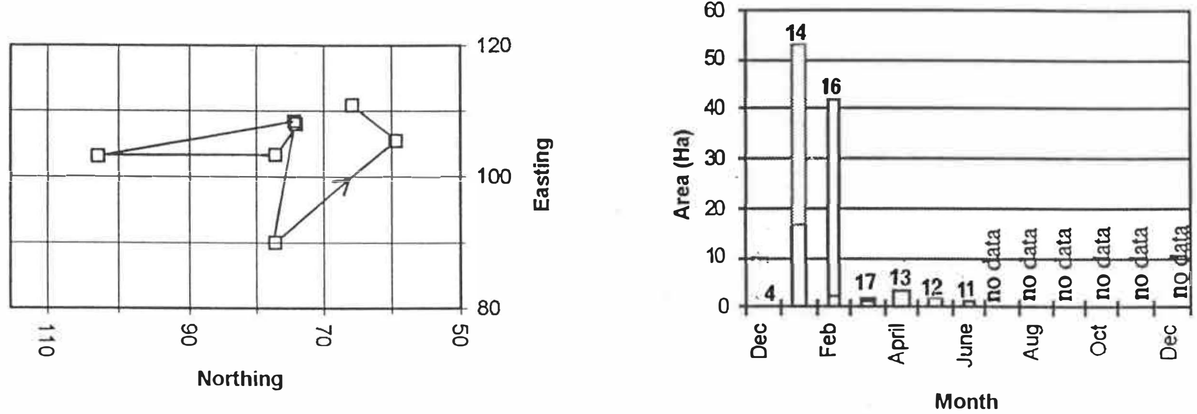
Bird 3 was the only bird that had any of its activity centres in the exotic forest. For two months (September and October), this bird based most of its activities within a small area of exotic forest (Figure 2.4). This was also the period when Bird 3's monthly home ranges were at their largest. For this bird, the largest shift in the monthly harmonic mean centre of activity was 501m. This coincided with the movement of the bird's activity centre from the exotic forest in October into the native forest in November (Figure 2.4).

FORT ROAD

Kaka 1



Kaka 2



Kaka 3

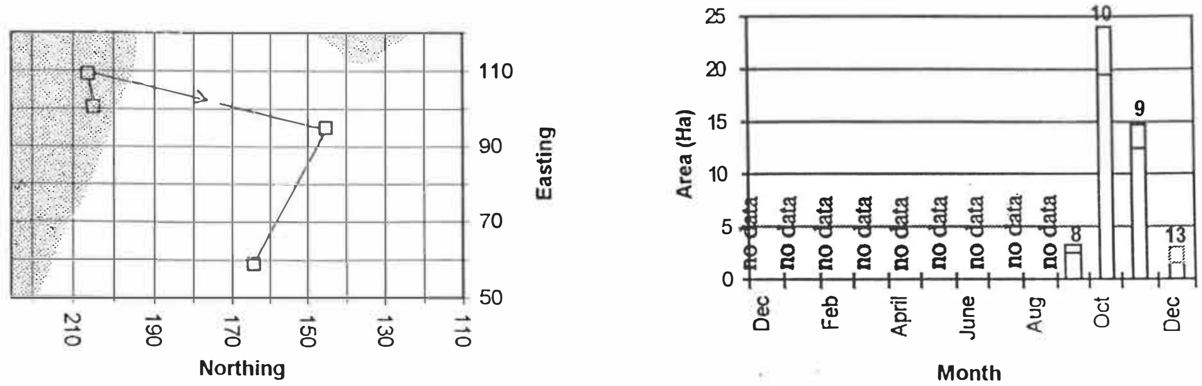
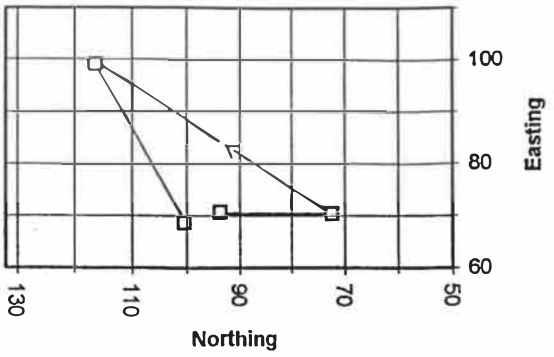
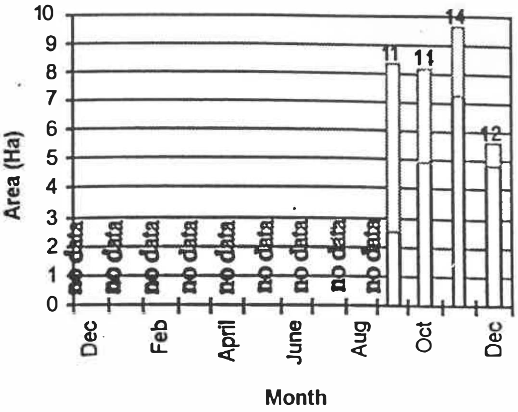


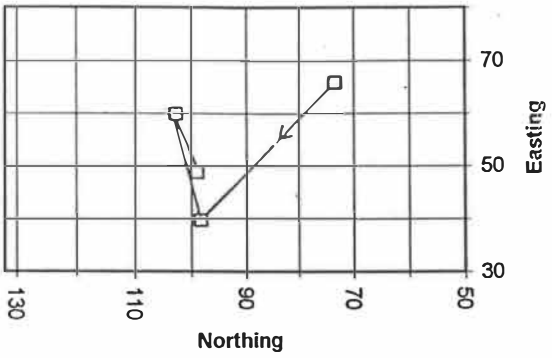
Figure 2.4 *Monthly changes in home range use. The figures on the left show changes in the harmonic mean centre of activity for each month. The stippled area is the exotic forest. The figures on the right show monthly changes in the area of 95% MCPs. The dotted bar shows the 100% MCP area, while any line intersecting the main bar is the 90% MCP area - these only occur when they differ from the 95% MCP area. The number at the top of each bar is the number of times the bird was located in that month.*

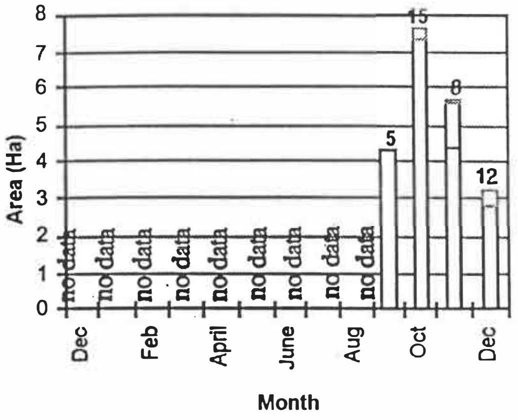
Kaka 4





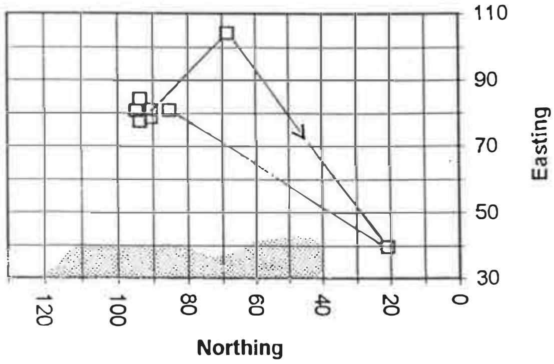
Kaka 5





TOTARA SALVAGE ROAD

Kaka 6



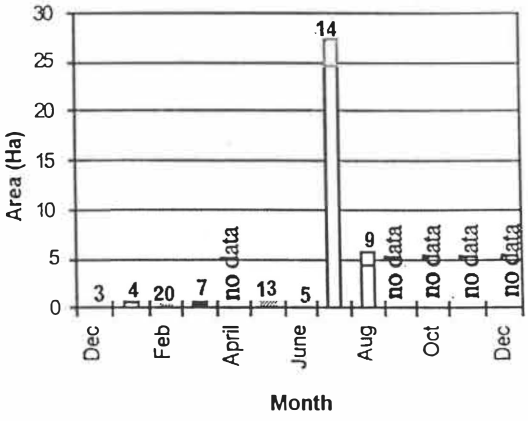


Figure 2.4 *(ctd)*

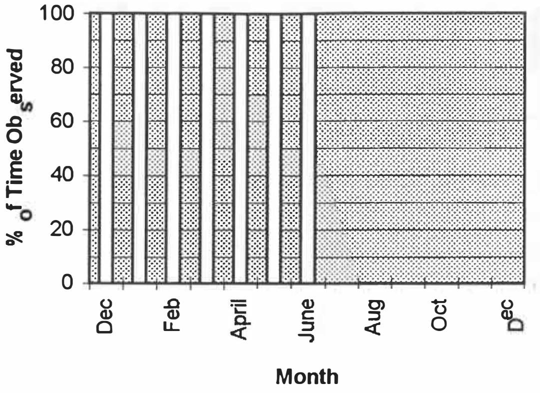
Bird 6 had an 80-fold expansion in its home range size in July. A large shift (640m) also occurred in the bird's harmonic mean centre of activity at this time; up to then, the bird had not moved its monthly centre of activity more than 50m (Figure 2.4). The large size of the 95% MCP areas during January and February for Bird 2 (Figure 2.4) coincides with a time when the bird was flying long distances into the exotic forest (Figure 2.2). Bird 3 had its peak in home range size during October when it was in the exotic forest (Figure 2.4). Generally though, the only evidence for any seasonal changes in home range size that had an effect on all of the birds simultaneously was that peaks in home range area occurred during October and November for all of the birds whose transmitters were functioning at this time.

Time spent in the exotic forest

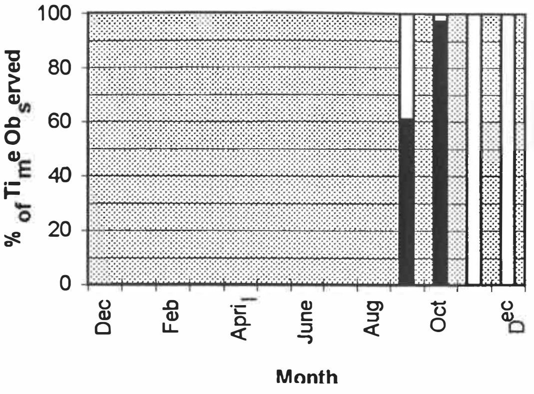
Four of the six birds spent 100% of their observed time in the native forest. Of the 2 that spent any time in the exotic forest, only one (Bird 3) was observed to use it substantially. This bird spent 61% of its observed time in the exotic forest during September and 97% in October (Figure 2.5). There were no observations of this bird in the exotic forest after these two months (Figure 2.5) which coincides with the shift in its activity centre from the exotic forest into the native forest (Figure 2.4).

FORT ROAD

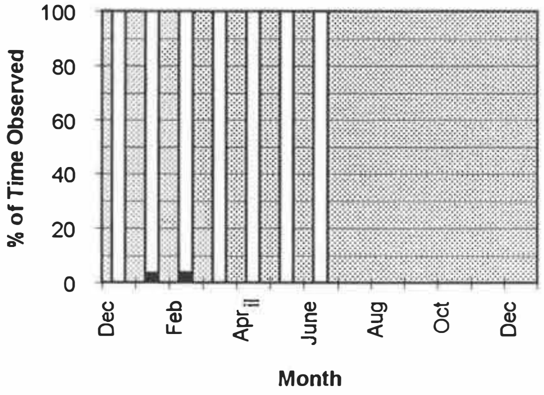
Kaka 1



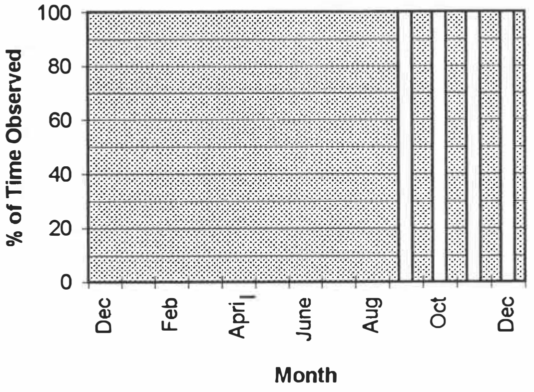
Kaka 3



Kaka 2

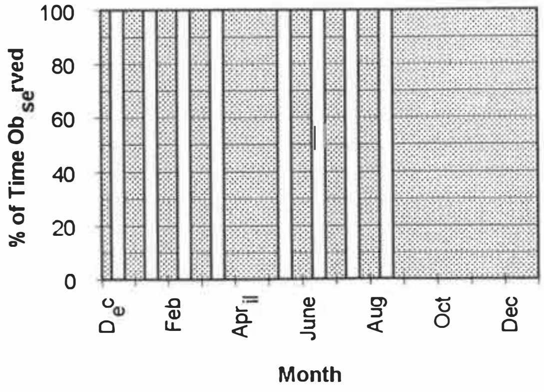


Kaka 4



TOTARA SALVAGE ROAD

Kaka 6



Kaka 5

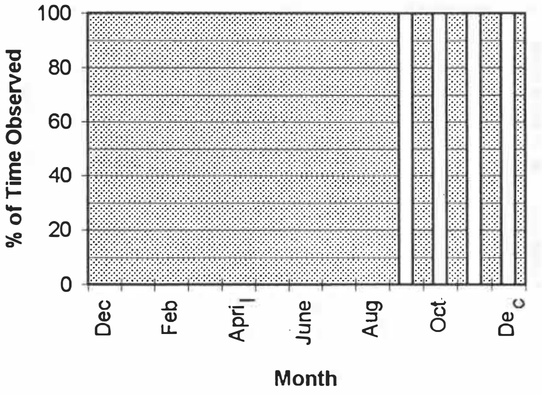


Figure 2.5 *The proportion of observation time spent in the exotic forest (black) and the native forest (white) each month.*

DISCUSSION

The home range of kaka

Radiotelemetry provides a powerful method for gathering unbiased data on an animal's use of its habitat. Although the number of radio fixes per animal determines the accuracy with which home ranges are determined, it is the number of animals tracked that determines the sample size upon which these results can be applied to a population (Aebischer *et al* 1993). My study had a low sample size, therefore, generalising my findings to a population level would be unwise. However, I did obtain a large number of observations for each animal so the individual profiles are detailed and reliable.

The home range sizes of the birds I studied (Table 2.2) were much smaller than those reported for South Island birds (O'Donnell & Rasch 1991). The birds I studied were reasonably localised in where they spent the majority of their time (Figure 2.3), with the birds often returning to the same position, even the same tree, within the forest throughout the year (pers obs). This difference in home range size could be due to the greater diversity, and density, of food in the North Island podocarp forests as opposed to the predominantly beech (*Nothofagus*) forests of South Westland (Kikkawa 1975, Craig *et al* 1981, Wardle 1984, Lee *et al* 1991); however, O'Donnell and Dilks (1994) have suggested that beech forests are not as barren as these studies suggested. Food sources do seem more widely spaced in beech forests though, with birds moving from high altitudes where they fed on rata sap in August, to low altitudes in October to feed on fuchsia (O'Donnell 1991). Kaka in the North Island podocarp forests may not have to cover these large distances to find the diverse range and quantity of foods they require. This is reflected in the observation that the dense podocarp forests of the Whirinaki area support higher numbers of kaka than any other forest type in this area (Moynihan 1979, Moynihan *et al* 1979).

If these differences in home range size are related to the availability and locations of a diverse range of foods, then competition with possums for these resources in the native forest (Wilson 1984, Beggs & Wilson 1991, Moorhouse 1991, Butler 1992) might be expected to impact on kaka's habitat use. For example, competition with possums may cause changes in home range size or decreases in kaka numbers. Insley (1993) suggested that competition with possums may have been the reason why kaka started utilising an alternative food source such as plantation trees.

Four of the five kaka had some degree of overlap in their home ranges (Figure 2.2). However, the positions of their centres of activity (Table 2.2) and how much time they were observed to spend at each position within their ranges (Figure 2.3) both implied that the degree of overlap may be less than their MCPs suggest (Figure 2.2). Even so, some degree of overlap in ranges did occur and this was not totally unexpected. Kaka utilise resources (eg fruiting trees) that are spaced in clumps and are somewhat unpredictable in their yearly supply of these resources. This sort of resource distribution does not lend itself to territoriality but rather colonial living or even nomadism (Brown 1964). Kaka were never seen to display any signs of territorial behaviour and several individuals were often observed on the same tree at the same time feeding on the same food source (pers obs). The lack of territorial behaviour may be due to a number of factors including resource abundance, a high density of birds, and low reproductive rates (Brown 1964); in particular, when the energetic cost of sharing resources are less than the costs of defending the territory against all intruders (Rolando *et al* 1995).

Seasonal changes in the home range of kaka

If an animal travels only within a small part of its range while the researcher is present on a single fieldtrip, then no matter how often this animal is sampled during this time, it will not truly reflect the total range. A more accurate picture of home range can only be gained by sampling over the course of many fieldtrips. Several authors have shown that home range size increases with sample size until an asymptote is reached (Kenward 1990, Barea 1995, Rolando *et al* 1995) but the number of sample points needed to reach this point seems to depend on the frequency, period and style of sampling, as well as the behaviour of the particular species being studied (Weavers 1993). With incremental area analysis (Kenward 1990) the sample points for the birds sampled in my study reached an asymptote quickly but, with continued sampling, would then increase again until a new asymptote was reached. This suggests that although these kaka had a localised home range they used different areas of this throughout the year. Although the transmitters did not have a long enough life for me to discover if the birds would return to their original area of use at the start of the next season, I susspect that this would be the case. It is possible that these shifts in home range position are related to the location of available food.

The changes in Bird 6's home range during July and August (Figure 2.4) coincided with a time when there were few food sources available within the native forest (Chapter 3). These changes may reflect a need to travel further to find food in sufficient quantities to satisfy dietary requirements. The bird was not observed to feed on sap at this time, suggesting that a shortage of food will not necessarily initiate sap feeding, at least in this individual.

All of the birds with functional transmitters during October and November had peaks in their home range area (Figure 2.4). Although it is unknown if these changes were due either to food availability or social activity (eg breeding), it seems likely that both these factors would have, at least, some effect on habitat use and possibly on the use of the exotic forest.

Use of the exotic forest by kaka

Most of the birds did not use the exotic forest even though they were all caught within flying distance of it (Figure 2.1). The one bird that was observed to use it extensively (Bird 3) did so for two consecutive months, and then abandoned it for the native forest (Figures 2.4 & 2.5). During this period, Bird 3 was observed to spend up to 97% of its time in the exotic forest (Figure 2.5); most of this time was spent bark stripping Douglas fir (Chapter 3), and its home range was comprised almost entirely of exotic plantation forest. This suggests that over this period, Bird 3 did not travel from the native forest into the exotic to sap feed, but instead focussed its activities within, or close to, the exotic forest (Figure 2.4). The absence of any overlap of Bird 3's home range area with the other kaka may suggest that this bird belongs to a different social group. It is possible that bark stripping in the exotics is a behaviour limited to certain individuals or groups. If bark stripping in the exotics is a behaviour learnt from other members of the population, then perhaps this technique has not yet been culturally transmitted throughout the population. This could account for why some birds do not use the behaviour.

All six of the birds I studied would have been capable of covering the distances required to feed in the exotic forest from their respective home ranges. For example, Bird 2 travelled 2km from its activity centre during an excursion into the exotic forest (Figure 2.2). Although it was not observed bark stripping, these excursions occurred at a time (February) when damage levels in the exotic forest were high (Chapter 3). This suggests that other birds could have been occassionally travelling to feed on exotic trees when their activities were focussed primarily in the native forest.

Use of the exotics may have been seasonal; most observations occurred at the start of spring (September and October; Figure 2.5). This timing of sap feeding behaviour is consistent with other reports, both for North and South Island birds (O'Donnell & Dilks 1986, 1994, Innes 1994; D Woodcock, DOC, pers comm). This coincides with a time when sap sugar levels are increasing within the trees (Kowlowski & Keller 1966, Beevers 1969, Zimmermann & Brown 1971, Cranswick *et al* 1987). The birds may feed on the sap of plantation trees when sugar levels are at their highest to maximise energy returns. This is also a period when there are few alternative food sources available in the native forest (Chapter 3). Perhaps the provision of an alternative food source with a higher net energy return, at this time, might cause the offending birds to cease this behaviour.

Bark stripping in the exotics does not seem to be a common activity amongst kaka. Two of the radiotracked birds were observed to conduct this activity in the native forest, but not in the exotic forest (pers obs). The one bird that was observed bark stripping in the exotics was a female (Table 2.1). In fact, the two females (Birds 3 and 4) accounted for 98% of all bark stripping observations of identified birds, both within the native and exotic forests. Also, on the eight separate occasions that pairs of birds were observed bark stripping in the native forest during the breeding season, it was always the female that was observed to be bark stripping while the male was perched nearby (pers obs). Bark stripping may be an activity mainly performed by females to gain access to a form of high energy food before breeding. Other studies have suggested that kaka will not breed in the absence of high energy foods (Moorhouse 1991, O'Donnell & Dilks 1994).

Chapter 3. Seasonal changes in diet and foraging behaviour of North Island kaka (*Nestor meridionalis septentrionalis*), with particular reference to sap feeding

INTRODUCTION

Gouging bark to produce a flow of sap is a rare feeding technique among vertebrates, but it has been recorded in primates, marsupials and woodpeckers (Oliver 1968, Rushmore 1969, Kinsey *et al* 1975, Coimbra-Filho & Mittermeier 1976, Ostrey & Nichols 1976, Smith 1982, Craig 1985). Kaka (*Nestor meridionalis*), an endemic New Zealand parrot, appear to be well adapted for this feeding method because they have a specialised brush tongue for collecting nectar and sap (Kirk *et al* 1993), as well as a powerful beak for removing bark.

Kaka have at least two distinct techniques for feeding on the sap of native trees (O'Donnell & Dilks 1989, O'Donnell 1993). One involves stripping bark and licking the exposed surface (see Chapter 1); the second technique is to tap small holes into the sap layer and lick the resulting exudate. Bark stripping appears to occur regularly on exotic plantation trees in the Whirinaki and Kaingaroa Forests (Chapter 1). The second technique appears to be rare in the Whirinaki area, because I never observed the technique, or its distinctive scars (O'Donnell & Dilks 1989), over the course of my study.

In an unpublished report, Insley (1993) suggested that increased levels of kaka damage in exotic forests may be associated with competition for food with possums (*Trichosurus vulpecula*). There is evidence of a possible high level of competition between kaka and possums for food (Veblen & Stewart 1982, Leathwick *et al* 1983, Elliot & Ogle 1985, O'Donnell & Dilks 1986, Rose *et al* 1990, Moorhouse 1991, O'Donnell & Rasch 1991). Also, possums are well established in the Whirinaki area (Beadel 1988, Innes 1994) where large amounts of kaka damage has been reported.

Although some information on the diet of South Island kaka (*N.r m. meridionalis*) is available (Beggs 1988, Beggs & Wilson 1987, 1991, O'Donnell & Dilks 1986, 1989, 1994) very little work has been done on North Island birds (*N. m. septentrionalis*), especially those on the mainland. South Island studies suggest that kaka are not generalist feeders; instead, they appear to be "sequential specialised feeders" (O'Donnell & Dilks 1994), moving from one food source to another seasonally (Beggs & Wilson 1987, O'Donnell & Rasch 1991, O'Donnell & Dilks 1986, 1989, 1994). It is not clear if this is the case for North Island birds.

In South Westland, the major components of kaka diet were invertebrates, nectar, fruit, seeds, and sap (O'Donnell & Dilks 1994); the food types they used varied markedly from season to season. Changes in food use were probably the simple result of changes in availability (O'Donnell & Dilks 1994). Nectar was most important during spring and summer (October-February) whereas fruit was important throughout autumn and winter. Sap feeding occurred mainly in late winter-early spring, with most observations occurring in August. This was a time when very few nectar sources were available, the kakas' energy demands were high and sap flow was increasing (O'Donnell & Dilks 1989, 1994).

O'Donnell and Dilks' (1994) observations are consistent with other mainland reports that suggest that kaka damage to trees, as the result of sap feeding, is seasonal, with most damage occurring in late winter and spring (Innes 1994; D Woodcock, DOC, pers comm). The timing of kaka damage could be related to seasonal changes in the sugar levels observed in tree sap. Starch and sugars are the primary storage products of plants and the concentrations of sugars are highest in pine sap from August to December; within this period, starch in the foliage and elsewhere is transformed into sugars during rapid growth (Cranswick *et al* 1987).

Cranswick *et al* (1987) found glucose, fructose, and sucrose to be the main sugars present in radiata pine bark, cambium and phloem. These are also the major components of beech honeydew (Grant & Beggs 1989) which Beggs and Wilson (1991) concluded was an important high energy food source for South Island kaka during the summer.

Obviously, a knowledge of an animal's diet is crucial for developing an understanding of an animal's biology, particularly in relation to conservation issues (Ramos 1995). O'Donnell and Dilks (1989) recognised the importance of kaka sap feeding behaviour to their long term conservation and suggested that further work in this area should be done. As a result, the objectives of this chapter were to determine:

1) the diet and feeding behaviour of North Island kaka and
2) any seasonal variation in diet or feeding behaviour that may be associated with sap feeding in plantation forests.

METHODS

Study sites

Feeding observations were conducted in the Whirinaki Forest, Bay of Plenty, New Zealand. Two study sites were used, the Totara Salvage Road area and the Fort Road area. For details on the characteristics of both these sites, and the periods over which they were used, see Chapter 2.

The Whirinaki Plantation Forest is described in detail in Chapter 1.

Diet and foraging

Two separate mist-netting sessions were conducted (one in September 1994, the other in September 1995) which resulted in six kaka being radiotracked over different periods until December 1995. The details of the birds, the capture sessions, and radiotracking regime are described in Chapter 2.

Kaka were tracked using a Telonics TR-4 receiver and a directional 3-element Yagi aerial. Once a bird was located a standard observation procedure was followed that allowed me to record the feeding activity, perch species, and location of the bird within the forest. Instantaneous samples (Altmann 1974) were collected every minute, once a bird was located to determine if it was feeding, what it was feeding on and the feeding technique used. The identity of individual plant species that kaka used either as perch sites or for food was recorded. Due to the difficulties associated with finding kaka, and the small sample size, observations were made consecutively for as long as the bird was in view, despite the possibility that this could result in an underestimation of the variation in food types selected (Hejl *et al* 1990). This method was similar to that used by Beggs and Wilson (1991), O'Donnell & Dilks (1988, 1994), and Garnett and Crowley (1995). All recording was done on a voice recorder and later transferred to a spreadsheet.

There were two ways that this data could have been handled; it could have either been pooled and then analysed, or individual means could have been calculated and then these means could have been analysed. Both of these approaches have problems. The results of pooled data are influenced by the disproportionate effects of long periods of observation on single birds (Hejl *et al* 1990, Garnett & Crowley 1995, Ramos 1995). Individual means have two problems associated with them. Firstly, data would be influenced by the disproportionate effects of short periods of observation. Secondly I would have to assume that I only encountered individual unidentified birds once. I do not know if this assumption is correct, especially considering that the birds I radiotracked stayed in the same areas. For these reasons, I chose to pool my data. This method of analysis is similar to that used by Beggs and Wilson (1991), Garnett and Crowley (1995), and Sodhi and Paszkowski (1995).

Food associated activities

The following feeding behaviours were recorded during instantaneous sampling:

(a) Berries	Manipulates and eats berries.
(b) Bark strip/sap	Strips bark off trees and/or feeds on sap.
(c) Cone seeds	Extracts seeds from cones and eats them.
(d) Other seeds	Manipulates and eats seeds.
(e) Fossicking/insects	Actively moves around the tree inserting beak into crevices etc, presumably in search of insects.
(f) Prising live wood/insects	Prising into live wood.
(g) Prising dead wood/insects	Prising into dead wood.
(h) Mossing/insects	Tears moss off tree limbs.

Non-feeding behaviours were also recorded during instantaneous sampling, but were not included for subsequent analysis.

Seasonal variation in kaka damage to plantation trees

To determine the frequency of damage by kaka over the course of a year, four transects (two through Douglas fir, *Pseudotsuga menziesii*, and two through radiata pine, *Pinus radiata*) were surveyed every month from January 1995 to January 1996. The sampled compartments were all classified as heavily damaged by a Forest Health Observers' survey conducted in 1993 (Chapter 1).

Compartments were surveyed by walking line transects. Pairs of trees every 25 paces were inspected with binoculars (Pentax $12x5^O$), until a total of 40 trees per compartment were examined. These trees were marked, numbered, and inspected during each subsequent transect.

Following the initial survey in January 1995 (Chapter 1), I recorded only the number of new and old damage scars on each focal tree as well as any evidence of ring-barking or crown dieback. The number of bark chips at the base of each tree was also counted. During each survey, tree bases were cleared of all bark chips arising from kaka damage. Therefore, any new bark chips around these trees provided a good indicator of new kaka damage. Fresh bark chips were spread around control trees to quantify rates of disappearance.

RESULTS

Diet and foraging

Table 3.1 shows the proportion of total feeding observations that kaka spent performing each feeding activity, and the species they fed on. The six kaka observed during this study used four main categories of food over the course of one year: berries (24.3% of all observations), sap (24.0%), seeds (29.8%), and insects (21.9%). Eleven different tree species were used for food and two of these were exotic. Of the natives, three species (matai *Podocarpus spicatus*, kahikatea *P. dacrydioides*, and miro *P. ferrugineus*), all podocarps, accounted for over half of all feeding observations.

Observations of feeding on two exotic species accounted for a large proportion (21.8%) of the total sample (Table 3.1). The main kaka feeding activity observed in radiata pine was feeding from cones, while in Douglas fir it was bark stripping. Bark stripping in exotics made up 38% of all sap feeding observations. Bark stripping is described in detail in Chapter 1. It should be noted that all bark stripping observations on Douglas fir were of only one bird. Tawa (*Beilschmiedia tawa*) was the main species that kaka stripped in the native forest, with a small amount also occurring on matai and Hall's totara (*P. hallii*; Table 3.1). Beech (*Nothofagus sp.*) was also used as a source of sap, but in the form of honeydew exudate from scale insects (*Ultracoelostome sp.*).

Table 3.1 *The percentage of time for which kaka were observed performing each feeding activity and the plant species that were used by kaka.*

Feeding behaviour	Berries	Bark strip /sap	Cone seeds	Other seeds	Fossicking/ insects	Prising live wood /insects	Prising dead wood /insects	Mossing /insects	TOTALS
Number of observations	369	366	251	203	163	93	45	31	1521
EXOTIC SPECIES									
Pinus radiata	_	0.1	12.3	_	_	_	_	_	**12.4**
Pseudotsuga menziesii	_	9.1	_	_	0.3	_	_	_	**9.4**
NATIVE SPECIES									
Podocarpus spicatus	7.2	1.6	4.2	_	4.9	4.0	1.9	0.8	**24.6**
Podocarpus dacrydioides	7.5	_	_	6.7	1.6	0.3	_	0.4	**16.5**
Podocarpus ferrugineus	9.2	_	_	_	2.5	1.8	0.8	0.9	**15.2**
Beilschmiedia tawa	_	9.4	_	_	0.1	_	_	_	**9.5**
Nothofagus sp.	_	2.5	_	5.0	_	_	_	_	**7.5**
Dacrydium cupressinum	_	_	_	1.6	0.9	_	0.2	_	**2.7**
Podocarpus hallii	_	1.3	_	_	_	_	_	_	**1.3**
Podocarpus totara	0.3	_	_	_	0.5	_	0.1	_	**0.9**
Knightia excelsa	0.1	_		_	_	_	_	_	**0.1**
TOTALS	**24.3**	**24.0**	**16.5**	**13.4**	**10.8**	**6.1**	**3.0**	**2.1**	**100**

Berries (or fruits) were observed to be taken from five species, mostly podocarps (99.6%), especially matai, miro and kahikatea (Table 3.1). The kahikatea berries were eaten whole due to their small size but the matai and miro berries required more handling. The birds would eat the outer layer of the berry then split the kernel and eat the inner seed.

The cones of only two species were used, and one of these was an exotic (Table 3.1). radiata pine cones were cracked open by kaka using their bill and then the seeds were extracted. Matai cones were eaten whole and formed a large part of the diet when available.

Insects also seemed to form a large part of the diet of kaka (Table 3.1). Generally, insects were gathered from a wide range of tree species, but specialised feeding techniques (ie mossing and prising) seemed to be more restricted in their use (Table 3.1).

Variation in diet between individual birds

Comparisons in diet can only be drawn between birds that were radiotracked over the same months. This gives two groups from which comparisons can be made: Birds 1, 2, and 6 (Group 1; tracked from December 1994); and Birds 3, 4, and 5 (Group 2; tracked from September 1995; Figure 3.1).

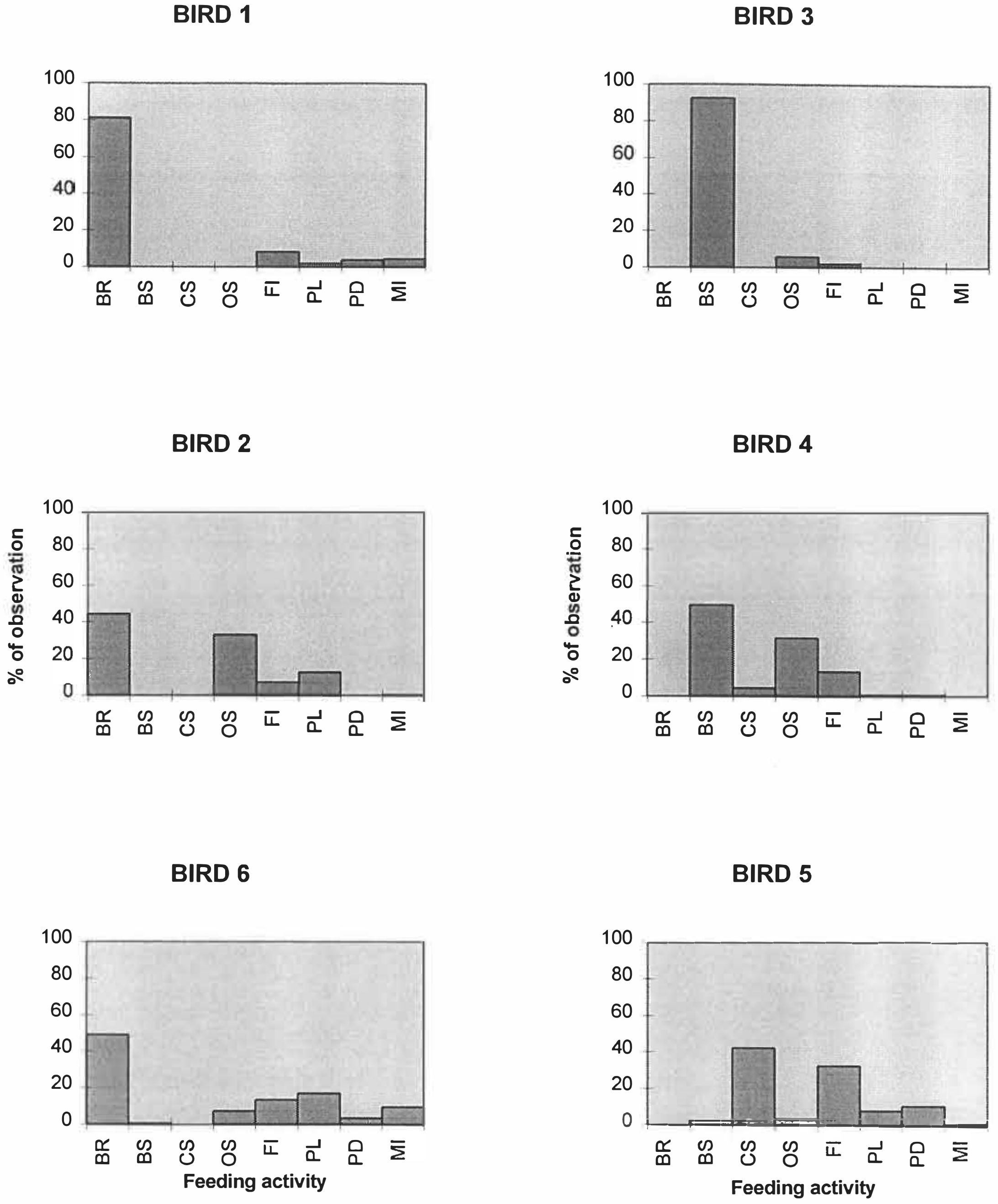


Figure 3.1 *Variation in diet between individual birds. The bars are the percentage of time that each individual bird spent on each activity. Feeding activities are: BR=berries; BS=bark strip/sap; CS=cone seeds; OS=other seeds; FI=fossicking/insects; PL=prising live wood/insects; PD=prising dead wood/insects; MI=mossing/insects.*

The diets of Group 1 all consisted of berries (58.2 ± 20.0%), seeds (13.5 ± 17.5%), and insects (27.5 ± 13.7%; Figure 3.1). These birds were observed feeding for a total of 154, 229, and 208 instantaneous sample minutes, respectively. Bird 6 was tracked for a longer period than the other two birds (Chapter 2), beyond the period of podocarp fruiting. Its use of insects (43.3% of its diet) was almost twice that observed for the other two birds (18.7% and 20.4%, respectively; Figure 3.1).

In Group 2 (Birds 2, 3, and 4), the females (Birds 2 and 3) appeared to differ in their use of bark stripping from the male (Figure 3.1). Bark stripping was very important to the females' overall diet, accounting for 92% of the feeding observations of Bird 3 (n=196; Figure 3.1). Although bark stripping comprised 49.4% of all observations for Bird 4 (n=158), seeds (36%) and insects (14.5%) were also important (Figure 3.1). The male (Bird 5) only spent 2.6% of its observed time (n=114) bark stripping, with insects and seeds making up the rest (97.4%) of its diet (Figure 3.1).

Seasonal variation in kaka diet

Seasonal changes in the diet of kaka were evident (Figure 3.2). Berries formed the bulk of the diet from January-June. Insects were important from March-October, while cones formed a large part of the diet in July and August and then again in December. Seed use (ie other than cones) peaked in February-March and then again from September-November. Sap feeding was the main feeding activity from September-November.

Even within each feeding category there were seasonal changes in the species used. For example, both radiata pine and matai cones formed part of the diet, but matai cones were only eaten when available in December. July and August was the other main period of cone feeding, this time from radiata pine (Figure 3.2). There were two separate periods during the year when kaka fed on seeds other than from cones (Figure 3.2). The first was in February-March when they fed exclusively on rimu and beech seeds, the other in September-November when only kahikatea seeds were taken. Kahikatea seeds were the previous season's fruit which had remained on the tree and dried out.

Kaka showed changes in their use of different berry species which may have been related to availability. Matai and miro berries were the only berries eaten from January-April, then kaka fed mainly on kahikatea (55% of berry feeding observations) from April-June.

Bark stripping formed the bulk (50% on average) of observations from September-December (Figure 3.2) and occurred mainly on two species. The exotic species Douglas fir was only used during September and October, and the native, tawa, mainly (92% of bark stripping observations on tawa) from October-December.

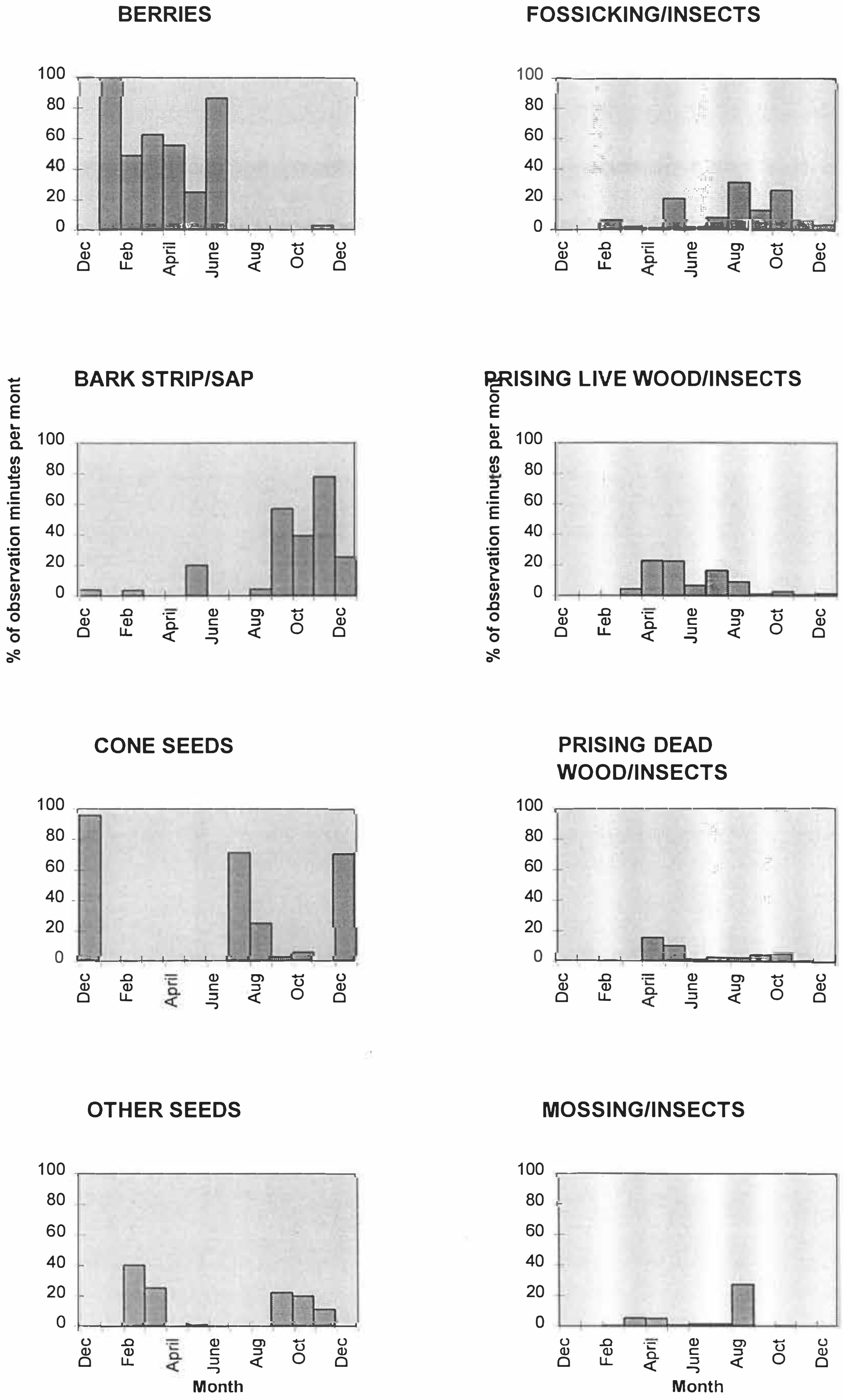


Figure 3.2 *Seasonal changes in diet of North Island kaka. The bars show the proportion of each month's observations spent at each feeding activity.*

Seasonal changes in levels of kaka damage to plantation trees

The number of new damage patches (bars in Figure 3.3) occurring was high in February and March and then again in September (Figure 3.3). The lowest number of new patches occurred in June and in December. The total number of damage patches, from kaka bark stripping behaviour, on the 160 trees in the monthly transects, rose by 190% (118 patches) over the course of the year (Figure 3.3).

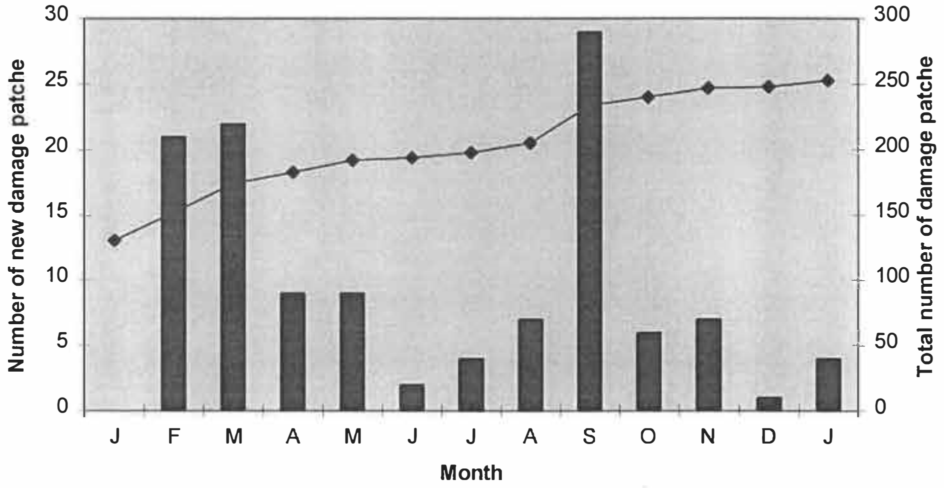


Figure 3.3 *Seasonal variation in the frequency of kaka damage. The line shows the cumulative number of damage patches (see Chapter 1), present each month within the four surveyed compartments (N=160 trees). The bars show the number of new damage patches present each month.*

The number of Douglas fir trees with bark chips beneath them was also at a maximum in February and again in September; few chips were found in July and December-January (Figure 3.4). Although the frequency of occurrence of kaka damage dropped to very low levels at various times throughout the year, it never ceased completely. The bark chips I placed beneath trees to investigate disappearance rates did not disappear, but due to the density of undergrowth in the radiata pine compartments, it was often difficult to find new chips. For this reason only the data on bark chip numbers collected from the Douglas fir compartments were used.

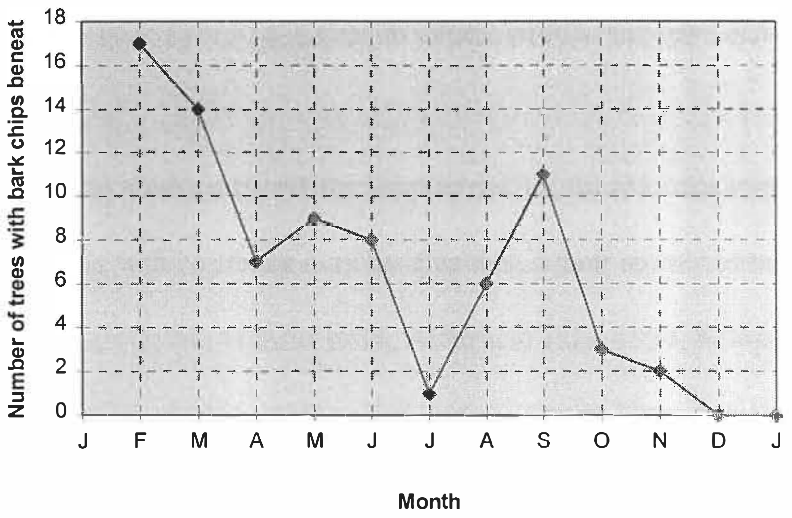


Figure 3.4 *Monthly variation in the number of Douglas fir trees with fresh bark chips beneath them as a result of kaka damage.*

DISCUSSION

Diet and foraging

The feeding observations collected over the study period suggest that kaka have broad omnivorous diets. O'Donnell and Dilks (1994) suggested that a widely omnivorous diet may be one of the factors aiding the survival of this species. Of the four identified components of kaka diet (berries, seeds, insects and sap), all contributed almost equally to the total feeding observations (Table 3.1). This suggests that the collection of sap by bark stripping is a major source of food for these kaka.

Podocarps are a vital source of food for kaka in the Whirinaki, supplying the bulk of the berries and seeds, although they may be irregular in their supply of this (Hinds and Reid 1957, Beveridge 1964, Wardle 1984, Allen and Platt 1990, Burrows and Allen 1991). Two or three good fruiting years can occur in a row, but generally they are 3-5 years apart (O'Donnell and Dilks 1994). It has been suggested that a full masting event, or at least an abundance of food, is required to initiate breeding in kaka (Moorhouse 1991, O'Donnell & Dilks 1994); breeding activity was observed during my field season, a heavy masting year. Despite this mast, kaka damage to the exotic forest still occurred. In fact, one of the peaks in damage levels occurred during the period of berry availability (Figures 3.2 & 3.3). This suggests that competition for food with introduced mammalian browsers may only be a contributing, not a determining, factor for why kaka continue to damage exotic trees.

Kahikatea fruits more heavily than other podocarps; one tree may bear over 800kg of fruit (Beveridge 1964). However, kahikatea also has the longest interval (up to seven years) between fruiting years (O'Donnell and Dilks 1994). Kahikatea bore fruit in 1995 and was also used extensively by kaka in this study (16.5% of all feeding observations); both the fruit and kahikatea seeds were used by kaka. Kahikatea were also a source of insects (Table 3.1). Even so, kaka damage still occurred within the exotic forest while these food sources were available (Figure 3.3). The importance of podocarps to kaka is reflected in the finding that dense podocarp stands support more kaka than any other forest type in Whirinaki (Moynihan 1979, Moynihan *et al* 1979).

Like their South Island counterparts (Beggs & Wilson 1987, O'Donnell & Dilks 1994), North Island kaka seemed to have a variety of specialised foraging techniques which they applied to specific situations. For example, when searching for insects kaka used one of three specialised feeding techniques: fossicking, prising or mossing (Table 3.1). Fossicking, the least specialised of the techniques, was used on the widest variety of tree species. The other two techniques are more specialised and were used less by kaka, on fewer tree species. The birds' choice of technique seemed to depend on the prey they were seeking, and on the physical characteristics of the area they were searching.

Although there were no observations of kaka feeding from flowers over the sampling period, they were observed feeding from kowhai (*Saphora microphylla*) flowers during preliminary field work in November 1994. The birds licked nectar from the flowers without causing any damage to them. O'Donnell and Dilks (1986) found that nectar from the flowers of southern rata (*Metrosideros umbellata*) and mistletoe (*Peraxilla sp.*) formed a large part of the diet of South Island kaka in South Westland. Both rata and mistletoe are missing from the Whirinaki Forest, presumably as a result of possum browsing. Possums are well established in the Whirinaki Forest, and these two plant species are rare in any forest where this is the case (Wilson 1984, Ogle & Wilson 1985). It is possible that competition with possums for resources in the native forest may have contributed to a further decline in kaka numbers, or forced the birds to start utilising alternative food sources such as plantation trees.

Honeydew is an important dietary item for South Island kaka (Beggs & Wilson 1987). Although I observed birds feeding on honeydew in beech trees, on all other occassions they collected sap by bark stripping. Beech trees form only a small proportion of all trees in the podocarp forests of the Whirinaki area. Almost all (86%) bark stripping events were associated with two species; one exotic (Douglas fir) and one native (tawa; Table 3.1).

Variation in diet between individual birds

Birds 1,2, and 6 were radiotracked when the podocarps were fruiting. Subsequently, feeding on podocarp berries comprised at least half of the feeding observations for these birds (Figure 3.1). Bird 6 was tracked beyond this fruiting period and insects were of increasingly important for this bird (Figure 3.1). This suggests that the diet of kaka is dependent on the availability of various food types.

Bark stripping was the main feeding behaviour performed in the second group (Figure 3.1). This activity seemed to be performed mainly by the females, but it should be remembered that only one male was radiotracked during this period. Bark stripping may be an activity performed by female kaka to gain access to a source of high energy food before the breeding season. Moorhouse (1991) suggested, after a study of kaka productivity, that an abundance of food is required for successful breeding in kaka.

Seasonal variation in kaka diet

Since the present study spanned only a single year and investigated the behaviour of only six kaka, it is necessary to be conservative when interpreting the seasonal changes I observed. However, the diet of North Island kaka in the Whirinaki Forest varied considerably through the year (Figure 3.2) and this appeared to be related to food availability. Kaka appear to be 'sequential specialist feeders' (O'Donnell & Rasch 1991, O'Donnell & Dilks 1994), applying specialised feeding techniques to specific food sources seasonally.

My observations and those of O'Donnell and Dilks (1994) indicated that most podocarp species carried fruit from autumn to winter and were an important food for kaka over this period. Feeding on insects seemed more frequent from March-October when fruiting had finished and few alternative food sources were available, whereas sap feeding was not predominant until near the end of the year (Figure 3.2). Sap feeding also occurred when food was not in short supply, suggesting that sap feeding is related less to a shortage of food than it is to seasonal changes in sap sugar content; this was measured as part of this study but the results are not yet fully analysed.

Sap feeding may be seasonal becausemost observations of it occurred in late winter and spring (Figure 3.2). Sap feeding behaviour did not overlap fruiting, but did occur in conjunction with seed and insect feeding (Figure 3.2). Sap feeding in South Westland also occurred mainly in late winter and early spring, with most observations occurring in August (O'Donnell & Dilks 1986, 1994). The difference in the timing of sap feeding in the native and exotic forests could be related to variation in the timing of peak sap sugar levels in each species. There was a lot of variation in the use of the exotic forest by individual birds. Only one of the six radiotracked birds used the exotics extensively. Why only this one bird used the exotics is unknown. The bird could have "discovered" a source of food that other kaka in the population have yet to exploit. It is possible that the feeding technique is culturally transmitted and is slowly spreading through the Whirinaki kaka population.

The seasonal variation in the diet of kaka I observed was difficult to compare to seasonal changes in home range size due to the effect that social events such as breeding may have on movement patterns. However, a particularly interesting change in home range size occurred between the 'berry' and 'sap feeding' periods, when there were few other alternative food sources. Although only one bird had an active transmitter during this period, a huge (80-fold) expansion in the home range size of this bird occurred, which could have reflected the need to have a larger foraging area within which to find food. The changes in home ranges sizes of kaka in the Whirinaki area (Chapter 2) could be related to the diversity and abundance of food within the podocarp forest. The larger home ranges of South Island birds (O'Donnell & Rasch 1991) could reflect the lower diversity of food types in beech forest (Kikkawa 1975, Craig *et al* 1981, Wardle 1984, Lee *et al* 1991).

Seasonal changes in levels of kaka damage to plantation trees

The peaks in damage to trees in the Whirinaki Plantation Forest occurred in early autumn (February-March) and the start of spring (September; Figures 3.3 and 3.4). Both of these times are periods when sap sugar levels peak in plantation trees (Mead & Will 1976, Cranswick *et al* 1987). The two periods when damage levels were lowest, mid-winter (June) and mid-summer (December; Figures 3.3 and 3.4), were periods of low sap sugar levels. Early spring was also the time when, for one of the birds, sap feeding in exotics appeared to make up a large proportion of its diet (Figure 2.4).

Although the reasons why kaka feed on sap in the exotic forests are still unclear, the timing of sap feeding may be related to the increases in the transport sugars of the sap. I suggest that the timing of this behaviour may have little to do with a shortage of alternative food sources, either because of season or browsing by possums. A number of reasons can be proposed. Firstly, sap feeding in the exotics occurred throughout the year, regardless of the quantity of alternative food sources. For example, the peak in sap feeding during early autumn coincides with a time when berries were readily available and sap feeding did not occur more often when there appeared to be a shortage of alternative foods. If food availability was a determining factor, we would expect sap feeding to be evident during June-August when the berries had finished. Finally, if sap feeding was due to anything apart from sugar levels, we would not expect the difference in timing between sap feeding in Douglas fir and tawa, or synchrony between kaka damage frequency and periods of high sap sugar levels in the exotic trees. A study of the seasonal changes in the sap sugar levels of tawa would be of interest to determine if these levels peaked during November-December; the period when most sap feeding observations on tawa were collected.

Transport sugars are at their highest concentrations near the beginning of autumn and spring, and at their lowest near the beginning of winter and summer (Kowlowski & Keller 1966, Beevers 1969, Zimmermann & Brown 1971, Cranswick 1978). Therefore, it seems that bark stripping would be more energetically viable when sap sugar levels are high, especially since excavation techniques were found to be energetically expensive for kaka (Beggs & Wilson 1987). Like kaka, yellow-bellied gliders also feed on sap predominantly in late winter (Smith 1982, Craig 1985).

Damage patches due to kaka increased on the 160 surveyed trees by 190% within just one year (Figure 3.3). The long term effect that this increase in damage has on the trees is unknown. The amount of damage that these trees sustained during this study does not appear to be normal, as these mature trees had only sustained, to that date, slightly more damage than they received in this one year. One explanation might be that damage is restricted to a few clumps of trees at any one time, with each bird returning to the same trees for consecutive feeding episodes. The trees damaged at this time would be damaged quite heavily (ie the number of damage patches would increase quite substantially) but would cease to be damaged when the birds moved to a new clump of trees. There was some evidence for this type of system. Radiotagged kaka regularly returned to individual trees both within the native and plantation forests; it also appeared that clumps of plantation trees were damaged for a period, and then left untouched for the remainder of the year (pers obs).

Kaka are "sequential specialist feeders" (O'Donnell & Dilks 1994) with four main components to their diet, the use of which varies seasonally. It seems that only a few of the kaka I studied utilise the exotic forest and this is mainly at the start of spring. The timing of this use could be related to increases in sap sugar levels at this time.

Summary

North Island kaka (*Nestor meridionalis septentrionalis*) damage plantation pines (*Pinus radiata* and *Pseudotsuga menziesii*) in the Whirinaki Forest. They do this by stripping the bark off the trunks to gain access to the sap. Although this activity appears to be widespread in the Whirinaki, my results suggest that kaka damage may have been limited to within 1km of the dense podocarp forests and was most extensive within 50m of this forest edge (Chapter 1). Also, those compartments that were close to these areas of podocarp forest used by kaka had the highest levels of damage. This suggests that kaka seek to maximise their energy gains by reducing the distance they travel to find food.

No relationship was found between DBH and damage or between physiography and damage (Chapter 1). Few studies to date have been able to determine why sap feeding animals target particular trees (Oliver 1968, Coimbra-Filho & Mittermeir 1976, Smith 1982, Craig 1985, O'Donnell & Dilks 1989), although Kenward *et al* (1988) found that grey squirrels were damaging those trees with the widest phloem layer. This could be a determining factor for kaka but further study is required to determine this.

In the two compartmnets that I surveyed for crown dieback over half of the trees suffering from crown dieback had no kaka damage at all and another 31% of these trees had only 1-2 damage patches. These small amounts of damage were unlikely to have caused crown dieback (D Smith, FRI, pers comm). As low as 14% of crown dieback may be due to kaka damage in these compartments. Other causes of crown dieback may include physical damage (other animals, wind, snow and land subsidence), poor drainage, nutrient deficiency, upper mid crown yellowing (UMCY), or pathogens (*Diplodia* and *Cyclaneusma*; Chapter 1).

The use of the exotic forest by kaka may have been seasonal. Most of my observations of kaka bark stripping were at the start of spring and the peaks in damage levels occurred at the start of spring and at the start of autumn (Chapter 3). Other studies have also found the start of spring to be the most important period of sap feeding for kaka (Innes 1994, O'Donnell & Dilks 1986, 1994; D Woodcock, pers comm). This timing may relate to increases in sap sugars during spring and autumn (Kowlowski & Keller 1966, Beevers 1969, Zimmermann & Brown 1971, Cranswick *et al* 1987). By using trees at these times, kaka would maximise energy returns from this energetically expensive feeding technique (Beggs & Wilson 1987). Perhaps the provision of an alternative high energy food source at this time would reduce bark stripping in the exotic forest.

Of the six birds I radiotracked, only one was observed to strip bark on plantation trees, but this behaviour seemed more common in the native forest (Chapter 3). For the two months (September and October) that this bird was observed using the exotic forest, it spent up to 97% of its time in it (Chapter 2). This bird (Bird 3) did not travel to the exotics to feed on sap but rather focussed its activities there for those two months (Chapter 2). It is possible that bark stripping in the exotic forests is a recent behaviour that is slowly being learned by the Whirinaki kaka population. If this was the case, damage levels could be expected to rise considerably in the future.

A number of findings suggest that female kaka may be the main bark stripping culprits. Firstly, the two females accounted for 98% of bark stripping observations recorded for the six identified birds within the native and exotic forests. Secondly, when pairs of birds were observed during the breeding season, it was always the female that was bark stripping (n=8 occasions). Finally, of the three birds radiotracked from September 1995, bark stripping was an important part of the diet for the two females but not the male. It has been suggested that kaka will not breed in the absence of high energy foods (Moorhouse 1991); sap may be used as a high energy food source by females before breeding.

Sap accounted for a substantial part of the overall diet of kaka (24% of 2628 one minute instantaneous samples of feeding). Sap seems more important for these kaka than for the South Island birds. Perhaps the absence of nectar sources in the Whirinaki Forest, due to extensive possum browsing, may have caused an increased reliance on sap. It is possible that competition with possums for food may be a contributing factor as to why kaka started sap feeding in exotics. Overall, the exotic plantation trees contributed to 21.8% of all feeding observations on all birds.

Innes (1994) suggested a number of techniques that could possibly be used to “protect trees” from kaka damage. These included supplementary feeding, decoy crops and possum control. Although supplementary feeding has the most potential to reduce the amount of bark stripping occurring in the exotic forest, it has a number of associated problems. Supplementary feeding is very labour intensive and there would be difficulties associated with targeting the appropriate birds. There are two reasons why possum control seems unlikely to be an effective option for reducing tree damage. Firstly, bark stripping in exotics appears to be an established feeding behaviour for certain individuals. Secondly kaka damage occurred throughout the year regardless of the quantity of food within the native forest (Chapter 3). A continued study of monthly damage levels (ie the number of Douglas fir trees with bark chips beneath) would provide an idea as to the effectiveness of any preventative measures and would allow monitoring of the damage levels from year to year.

The Whirinaki Forest is one of the last remaining areas of virgin, lowland podocarp forest. It supports large numbers of kaka and other threatened bird species including kakariki (*Cyanoramphus novaezelandiae novaezelandiae*), kereru (*Hemiphaga novaeseelandiae novaeseelandiae*), and karearea (*Falco novaeseelandiae*), as well as short and long-tailed bats. This area presents many opportunities for further research, especially studies in conservation management. Further research lines with kaka could include work on breeding success and how this relates to sap feeding and the provision of high energy food.

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