

**A study of home ranges, movements, diet and habitat use of kereru
(*Hemiphaga novaeseelandiae*) in the southeastern sector of Banks
Peninsula, New Zealand**

A thesis
submitted in partial fulfilment
of the requirements for the degree of
Master of Science
At
Lincoln University

By
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Lincoln University

2006

Frontispiece



Having just flown into a window of the Akaroa Museum, this kereru takes a moment to collect his/her thoughts (photo and caption: Michael Allen).

Abstract

The present study is part of the Kaupapa Kereru Programme. The main aim of the programme is to increase the numbers and range of kereru (*Hemiphaga novaeseelandiae*) on Banks Peninsula. Home ranges, movements, diet and habitat use of 15 kereru captured in Hinewai Reserve, Banks Peninsula, were investigated from February 2005 to February 2006. Hinewai Reserve is the largest tract of regenerating native forest in a highly modified urban-rural landscape. Phenology of 11 plant species predicted to be key kereru foods, was studied to determine the pattern of food availability in Hinewai Reserve. Twelve radio-tagged kereru resided in the Hinewai Reserve study site (Otanerito Valley and Sleepy Bay) and three resided in Akaroa.

Ripe fruit was available from January to August; the height of the fruiting season was in autumn. The bulk of new leaf growth occurred in spring and early summer although new leaves were available on broom and tree lucerne year round. Peak flowering occurred in spring.

Kereru in Akaroa ate a total of 21 plant species; six of these species were native and 15 introduced. Kereru in the Hinewai Reserve study site ate a total of 26 plant species; 20 of these species were native and six introduced. Fruit was preferred when readily available. Native fruit appeared to be preferred over fruit of introduced species in Akaroa, where both types were available. New foliage of introduced legumes and deciduous species appeared to be preferred over new foliage of native species at both sites during winter and spring. These species were important food sources prior to the breeding season and may be selected specifically for their nitrogen and protein content. Food is currently not a limiting factor for kereru survival or reproductive success.

Considerable variation in the use and preference of vegetation types of individual kereru made it difficult to identify trends in habitat selection. Use and preference for many vegetation types was seasonal; this was certainly because of the availability of food species included in or close to these vegetation types. Overall, native vegetation communities were used more than communities dominated by introduced species and forest communities were used more than non-forest communities. Kanuka (*Kunzea ericoides*) was used most often for non-feeding activities and 67% of observed nests were built in kanuka.

Annual home ranges and core areas in the Hinewai Reserve study site (mean of 15.9 and 2 ha respectively) were significantly larger than those found in Lyttelton Harbour, Banks Peninsula in previous research (mean of 8 and 0.08 ha respectively). Home ranges were larger when fruit was eaten, than when no fruit was eaten indicating that kereru are more sedentary when feeding on foliage. Kereru from the Hinewai Reserve study site made no excursions >5 km and no daily movements >2 km. Kereru from Akaroa and Sleepy Bay travelled into Otanerito Valley to feed on horopito in autumn, indicating that there may have been a lack of fruit in their local areas during autumn. No kereru in Otanerito Valley travelled outside of the valley.

The distribution of high quality food sources is likely to have caused the observed differences in home range and core area size between localities. Kereru in Lyttelton Harbour may have been restricted to small patches of high quality resources in a study area consisting largely of unsuitable habitat. In Hinewai Reserve, high quality resources were spread over larger areas and were more uniformly distributed. The density of kereru was unknown at both study sites, and this confounded assessment of habitat quality. However, it is likely that the Hinewai Reserve study site would support a higher number of kereru.

The main factor limiting population growth in the present study was failure of nests at the egg and chick stage. The fledge rate was 17%. Two of fifteen adult kereru died. Control of predators should be the first aspect of management that is focused on, and will almost certainly increase reproductive success of kereru and loss of breeding adults. As the population of kereru on Banks Peninsula increases due to predator control in existing kereru habitat, food may become a limiting factor. Habitat can be improved for kereru by planting a diverse range of plant species that provide food year-round. Native fruiting species are greatly recommended for habitat enhancement and should be selected so that fruit is available for as much of the year as possible. Native and introduced legumes should also be made available as foods for winter and spring.

As most land on Banks Peninsula is privately owned, co-operation and enthusiasm of the community is critical for successful management. Information and support needs to be given to landowners wishing to enhance their properties for kereru.

Acknowledgements

This research was funded by the Kaupapa Kereru Programme - a collaboration between Te Rūnanga o Ngāi Tahu, Lincoln University, Maanaki Whenua (Landcare Research) and the Department of Conservation. I am honoured to have been part of a fantastic iwi-led conservation project which encourages community awareness and participation.

A big thank-you to the Kaupapa Kereru Programme committee, the project would not have been so successful without their enthusiasm and hard work. Special thanks to the programme co-ordinators Takerei Norton and his successor Craig Pauling who made sure everything got done and who have supported me throughout my research.

Thanks to Terry Greene, Peter Dilks and Moira Pryde of the Department of Conservation for putting a lot of time and effort into catching and radio-tagging my kereru – it was fun! Thanks to Robin Burley, also of DOC, for scanning the bays for my missing kereru.

Hugh Wilson and the board of Hinewai Reserve - thank-you so much for allowing me full use of the reserve and for supplying me with accommodation. Hugh...you're a legend! Your company, advice and funny stories were invaluable ☺ I think of Hinewai often while I sit here writing in the car-infested swamp...

To my supervisors Kerry-Jayne Wilson and Shaun Ogilvie – you guys have been awesome. Thanks for giving me direction, assistance and for reading all my drafts. I've enjoyed having you along for the ride ☺ Thanks to all the other Lincoln University staff who helped me out during the study, especially Myles McIntosh for helping me in the field when I was injured and Alison Lister for giving me good stats advice. Thanks to my fellow students Maaike Schotborgh, Te Ari Prendergast and Jo Whitehead for giving me advice and help when I needed it.

Thanks to Brian and Faye Narbey, Fiona Farrell and Doug Hood and Frank Miessen for letting me roam your properties and showing interest in my research. Sometimes a chat with you guys was the only human contact I had in a day...thanks for keeping me sane! Thanks also to all the people in Akaroa who allowed me access to their properties.

Thanks heaps to John McIlroy who volunteered to proof-read my drafts - your attention to detail is amazing. You have stayed interested in my research from day one and I am grateful for all the time you have put into my work. Your feeding data from Akaroa was a bonus.

Thanks to Chris Robinson of the Ornithological Society of New Zealand for providing the provisional distribution map and getting it to me pronto.

To family and friends who have always been there for me. Mum, Dad, Jenny and Dorothy – I hope I have done you proud. Mike, Nori and Rick – thanks for letting me work at your place and for putting up with my music (it takes a bit of getting used to apparently) and my over-bearing ways ;-)

Abstract	iii
Acknowledgements	v
List of tables	xii
List of figures	xiii
CHAPTER 1: INTRODUCTION	1
1.1 Current Knowledge	1
1.1.1 Appearance and distribution	1
1.1.2 Breeding biology and behaviour	1
1.1.3 Diet	3
1.1.4 Home range and movements	4
1.1.5 Role in forest regeneration	5
1.2 Justification for the research	5
1.3 Objectives	7
CHAPTER 2: DESCRIPTIONS OF STUDY SITES	9
2.1 Characteristics of the Banks Peninsula landscape	9
2.2 Description and history of study sites	9
2.2.1 Hinewai Reserve study site (including Otanerito Valley and Sleepy Bay gully)	10
2.2.1.1 <i>Purple Peak Saddle</i>	12
2.2.1.2 <i>Lower Otanerito Valley and Sleepy Bay gully</i>	12
2.2.2 Akaroa study site (Akaroa township and surrounding farmland)	12
CHAPTER 3: CAPTURE AND RADIO-TAGGING OF KERERU	14
3.1 Capture of kereru	14
3.1.1 Capture sites	15
3.2 Fitting of radio transmitters and leg jesses	15
3.3 Radio tracking of kereru	18
3.3.1 Observations of tagged kereru	19
CHAPTER 4: PHENOLOGY	21
4.1 Introduction	21
4.2 Methodology	22
4.2.1 Selection of monitored individuals	22
4.2.2 Data collection	23
4.3 Results	24
4.3.1 Phenology of all species	24

4.3.2 Phenology of individual species	25
4.3.2.1 <i>Fruit</i>	25
4.3.2.2 <i>Flowers</i>	27
4.3.2.3 <i>Foliage</i>	27
4.4 Discussion	28
CHAPTER 5: FEEDING	32
5.1 Introduction	32
5.2 Methodology	33
5.2.1 Food species eaten	33
5.2.2 Relative importance of food species	34
5.2.3 Other feeding observations in Akaroa	34
5.2.4 Feeding in relation to phenology	35
5.3 Results	35
5.3.1 Species and food types eaten	35
5.3.1.1 <i>Hinewai Reserve study site</i>	35
5.3.1.2 <i>Akaroa study site</i>	35
5.3.2 Relative importance of kereru food species	35
5.3.2.1 <i>Hinewai Reserve study site</i>	35
5.3.2.2 <i>Purple Peak Saddle</i>	38
5.3.2.3 <i>Akaroa study site</i>	38
5.3.3 Proportion of food types eaten	38
5.3.3.1 <i>Hinewai Reserve study site</i>	38
5.3.3.2 <i>Akaroa study site</i>	38
5.3.4 Proportion of native vs. introduced species eaten	39
5.3.4.1 <i>Hinewai Reserve study site</i>	39
5.3.4.2 <i>Akaroa study site</i>	40
5.3.5 Other feeding results from Akaroa	41
5.3.5.1 <i>Species eaten</i>	41
5.3.5.2 <i>Proportion of food parts eaten</i>	41
5.3.5.3 <i>Proportion of native vs. introduced species eaten</i>	41
5.3.5.4 <i>Comparison with results from radio-tagged kereru in Akaroa</i>	41
5.3.6 Feeding in association with phenology	44
5.4 Discussion	45
5.4.1 Key findings regarding food species	45
5.4.2 Feeding in relation to phenology data	47

5.4.3 Suggestions for enhancing kereru habitat on Banks Peninsula	48
CHAPTER 6: HOME RANGE AND MOVEMENTS	50
6.1 Introduction	50
6.2 Methodology	51
6.2.1 MCP area, home range and core area calculations	51
6.2.1.1 MCP area calculation	51
6.2.1.2 Home range calculation	52
6.2.1.3 Assessing stability of home ranges	54
6.2.1.4 Comparing seasonal differences in home range size	54
6.2.2 Home range overlap	55
6.2.3 Timing and extent of movements	55
6.3 Results	56
6.3.1 Estimation of annual home ranges and core areas	56
6.3.1.1 Hinewai Reserve study site	56
6.3.1.2 Akaroa study site	57
6.3.1.3 Correlation between core area and home range size	57
6.3.1.4 Comparison of annual home range and core area size, and the number of nuclei in ranges, with the Lyttelton Harbour study site (Schotborgh, 2005)	57
6.3.2 Estimation of seasonal home ranges	58
6.3.2.1 Seasonal home ranges of kereru in the Hinewai Reserve study site	58
6.3.2.1 Seasonal home range of kereru in the Akaroa study site	59
6.3.3 Home range overlap	60
6.3.4 Timing and extent of movements	61
6.4 Discussion	63
6.4.1 Home ranges and core areas	63
6.4.2 Distance travelled	65
6.4.3 Home range overlap	67
6.4.5 Conclusions	68
CHAPTER 7: HABITAT USE	70
7.1 Introduction	70
7.2 Methodology	71
7.2.1 Digitisation of a vegetation map of the Hinewai Reserve study site	71
7.2.1.1 Digitising vegetation types within Hinewai Reserve	71
7.2.1.2 Digitising vegetation types outside the boundary of Hinewai Reserve	71
7.2.1.3 Creation of the final vegetation map	71

7.2.2 Calculation of the availability of each vegetation type within home ranges	71
7.2.3 Calculation of use of each vegetation type by kereru	72
7.2.4 Selection of vegetation types by kereru	72
7.2.4.1 <i>Changes in the selection of each vegetation type</i>	73
7.2.4.2 <i>Selection of vegetation assemblages</i>	73
7.2.5 Plant species used for non-feeding activities	74
7.3 Results	74
7.3.1 Vegetation composition of the Hinewai Reserve study site	74
7.3.2 Availability and use of vegetation types	78
7.3.3 Selection of vegetation types by tagged kereru	78
7.3.3.1 <i>Selection of vegetation assemblages</i>	80
7.3.4 Plant species used for non-feeding activities	83
7.4 Discussion	84
7.4.1 Selection of vegetation types	84
7.4.2 Selection of species for non-feeding activities	86
7.4.3 Conclusions	88
CHAPTER 8: GENERAL DISCUSSION	89
8.1 How did the present study contribute to the Kaupapa Kereru Programme?	89
8.2 How did this study contribute to knowledge of kereru in the wider context?	89
8.3 Quality of the Hinewai Reserve, Akaroa and Lyttelton Harbour study sites as kereru habitat	90
8.4 Seed dispersal by kereru in regenerating forest habitat	91
8.5 Monitoring of kereru on Banks Peninsula	93
8.5.1 Cue counting from vantage points (from <i>Bibby et al.</i> , 1998: 70-71).	94
8.6 Key findings important for management	95
8.7 Management of kereru	98
8.7.1 Management recommendations	98
8.7.2 The value of introduced plant species in habitat restoration	100
8.8 Future research	100
References	102
Appendix 1: Frequency, sex (determined only for breeding kereru), date of capture, catch site, and area of residence (area containing >90% of location fixes) and number of observation periods (n) for each kereru.	107
Appendix 2: Data sheet used to record observations	108

Appendix 3:	Proportion of feeding observations recorded on each species (A) and proportion of kereru recorded eating each species (B) at three sites. Shaded values are above the 0.4 threshold.	109
Appendix 4:	Full list of species eaten by kereru in Akaroa and Otanerito Valley and food species not eaten by kereru in this study but which are present on Banks Peninsula.	112
Appendix 5:	The number of locations needed for incremental area plots of the MCP and home ranges to reach stability. Home ranges that did not reach stability are shown with a (-).	114
Appendix 6:	Notes on breeding kereru in the Akaroa and Hinewai Reserve study sites	115

List of Tables

Table 5.1. Summary of feeding periods in relation to availability of monitored species.	44
Table 6.1. Estimates of MCP area and annual home ranges (HR) and core areas (CA) at the Hinewai Reserve study site and Akaroa study site. See 6.2.1 for explanation of these terms.	56
Table 6.2. Breeding and non-breeding home ranges of breeding kereru.	58
Table 6.3. Estimates of seasonal home ranges of kereru in the Hinewai Reserve study site and Akaroa study site using cluster analysis.	59
Table 6.4. The number of times any two kereru overlapped home ranges and the average proportion of home range overlap for the fruit-eaten and no-fruit-eaten seasons.	60
Table 6.5. The proportion of movements made in each distance category at the Hinewai Reserve and Akaroa study sites during the fruit-eaten and no-fruit-eaten seasons.	63
Table 7.1. Percent of each vegetation type within annual and seasonal home ranges (availability) and the percent of locations for each kereru in each vegetation type (use). Due to slight inaccuracies of the vegetation map percentages do not add to 100 (see 7.2.2).	79
Table 7.2. Selection of vegetation types by each kereru during the full year, when fruit was eaten, and when no fruit was eaten. Jacob's index values range between -1 and +1. Values >0 indicate preference and values <0 indicate avoidance. Data for kereru #60 and 68 was only available for the fruit-eaten season. (-) indicates the vegetation type was absent from the home range.	79
Table 8.1. Plant species most frequently used for non-feeding activities.	98

List of Figures

- Figure 1.1. The distribution of kereru recorded between 1999 and 2004. Shaded squares show where kereru were recorded. Blank squares were searched but kereru were not recorded. Crosses indicate the square was not searched (OSNZ, unpublished). 2
- Figure 2.1. Map showing Banks Peninsula and locations of Akaroa Township and Hinewai Reserve (adapted from: Allen, in prep). 10
- Figure 2.2. Photo of Hinewai Reserve and lower Otanerito Valley (left) and Akaroa Harbour and Township (right). 12
- Figure 2.3. Aerial photo of the southeast corner of Banks Peninsula showing a rough outline of Hinewai Reserve and highlighting important areas within the study sites. 13
- Figure 3.1. Number of kereru available for data collection in all areas. 14
- Figure 3.2. Map of the wider Akaroa area showing Hinewai Reserve and locations of the Otanerito Homestead and Purple Peak Saddle capture sites (adapted from Wilson, 1995). 16
- Figure 3.3. A) Mist nests were set up between feeding and resting sites (Peter Dilks of DOC in the foreground, photo: T. Greene). B) kereru with a partially fitted nylon harness and transmitter. 17
- Figure 3.4. Radio-tagged kereru with a yellow leg jess clearly visible (photo: K-J Wilson). 17
- Figure 4.1. Average abundance score of foliage (A), flowers (B) and ripe fruit (C) for all monitored species over a 13-month period. 24
- Figure 4.2. Average abundance of ripe and unripe fruit for each monitored species over a 13-month period. 26
- Figure 4.3. Average abundance of flowers on monitored species over a 13-month period. 27
- Figure 4.4. Average abundance of mature and immature foliage on monitored species over a 13-month period. 28
- Figure 5.1. Food species and food types eaten over time in two areas: Hinewai Reserve and Akaroa. Introduced species are marked with a (*). 36
- Figure 5.2. The relative importance of species over time at three sites: Hinewai Reserve, Purple Peak Saddle and Akaroa. No feeding observations were made on kereru at Purple Peak Saddle during two weeks in August. 37
- Figure 5.3. The proportion of each food type consumed over time in two areas: Hinewai Reserve and Akaroa. 39
- Figure 5.4. The proportion of native and introduced species eaten over time in two areas: Hinewai Reserve and Akaroa. 40

Figure 5.5. Plant species and food parts eaten by untagged kereru between April 2003 and February 2006 in Akaroa.	42
Figure 5.6. The proportion of food parts eaten by untagged kereru in Akaroa between April 2003 and February 2006.	43
Figure 5.7. The proportion of native vs. introduced species eaten by untagged kereru in Akaroa between April 2003 and February.	43
Figure 6.1 Simplified diagram of nuclei (cluster) formation.	52
Figure 6.2. Aerial photo overlaid with the outer-MCP, home range and core area of kereru # 40. The home range consists of two nuclei (or clusters). Within the home range is the core area consisting of five nuclei	53
Figure 6.3. Utilisation plot used to determine the percentage of locations included in the core area.	54
Figure 6.4 The proportions (%) of home range overlap between all tagged kereru for each season. Kereru # 52, 54 and 66 were residents of Akaroa; kereru # 62 resided in Sleepy Bay gully. All other kereru were residents of Otanerito Valley.	60
Figure 6.5. Number of home range overlaps occurring in each percentage category for kereru at both study sites.	61
Figure 6.6. The number of long-distance movements (>1500 m between consecutive locations) made by all kereru each field week.	62
Figure 7.1. Vegetation map of the Hinewai Reserve study site and the proportion of each vegetation type in the reserve.	76
Figure 7.2. The proportion of kereru that preferred and avoided each vegetation type annually and each season. Blank spaces indicate that no kereru preferred or avoided the vegetation type in that time.	81
Figure 7.3. Kereru selection of native vs. non-native and forest vs. non-forest vegetation groups annually and seasonally.	82
Figure 7.4. Plant species used by kereru for resting and preening throughout the study period at the Hinewai Reserve study site. Frequency of use is expressed as a percentage. Species used <2% of the time were grouped together under 'other' on the basis of whether they were native or introduced.	83
Figure 8.1. Species eaten by kereru in this study and recommended for enhancement of habitat for kereru on Banks Peninsula. Scientific names are found in Appendix 4.	97

Chapter 1

Introduction

1.1 Current knowledge

1.1.1 Appearance and distribution

The kereru (*Hemiphaga novaeseelandiae*) is an attractive, large (550-850 g) fruit pigeon endemic to New Zealand (Clout, 1990). Adults are mostly metallic green with a purple and bronze sheen on the head and neck. The nape, hind neck, most of the saddle and smaller secondary wing coverts are a deeper purple and the lower back and upper tail a blue-grey colour (Higgins & Davies, 1996). The white breast and under body are sharply defined from the colourful upper body. The bill, eyelids, legs and feet are a dark crimson-red. Juveniles can be distinguished from adults by their duller green plumage, brown bill and eyes, and pink legs and feet (Higgins & Davies, 1996). Kereru can also be identified by their distinctive whooshing and clapping flight. Sexes are monomorphic and can only be identified by breeding behaviour or by DNA analysis.

Kereru inhabit a wide range of habitats including native and exotic forest fragments, rural and urban areas, but are found mostly in large tracts of lowland native forest on the mainland and on many offshore islands (Fig. 1.1) (Pierce & Graham, 1995).

1.1.2 Breeding biology and behaviour

Kereru form a monogamous pair-bond during the breeding season. This may last for more than one season and pairs have been known to associate during the non-breeding season (Higgins & Davies, 1996). Timing and duration of the breeding season appears to be linked with the availability of food that meets the nutritional requirements of breeding adults and possibly also fledglings (Clout, 1990; Schotborgh, 2005). Display flights performed by male kereru mark the onset of the breeding season (when kereru form pairs and begin nesting) (Pierce, 1993). Nesting usually starts in spring or early summer (Pierce, 1993) with a peak of laying between December and February (Clout *et al.*, 1991; Clout *et al.*, 1995). However nests have been found through most of the year in warmer parts of New Zealand (Clout *et al.*, 1995; James & Clout, 1996; Pierce & Graham, 1995). Pierce and Graham (1995) found that nests at Maungatapere, Whangarei, were usually placed in the upper-understory (average of 6.1 m) and

[Figure not available for publication]

Figure 1.1 The distribution of kereru recorded between 1999 and 2004. Shaded squares show where kereru were recorded. Blank squares were searched but kereru were not recorded. Plus signs indicate the square was not searched (by permission of OSNZ, unpublished).

in the lower understory (average of 2.1 m) on the Chicken Islands. They found nests in a total of 13 tree species on the mainland, of which totara (*Podocarpus totara*) and karaka (*Corynocarpus laevigatus*) were most commonly used. On the Chicken Islands, nests were found in six tree species of which kanuka (*Kunzea ericoides*) the most commonly used (Pierce & Graham, 1995). Schotborgh (2005) found that 2/3 of kereru nests in Lyttelton Harbour, Banks Peninsula, were built in kanuka. One egg is laid per clutch, resulting in a naturally low reproductive rate (Clout *et al.*, 1995). However, longevity is at least 6 years and some kereru may live to at least 10 years of age (Clout *et al.*, 1995). Re-nesting attempts may be made later in the breeding season, often following previous nest failure (Clout *et al.*, 1995; Mander *et al.*, 1998; Schotborgh, 2005). It is possible for kereru to fledge two chicks in a single breeding season when sufficient food is available (Schotborgh, 2005). Incubation lasts 28-29 days and is shared by the male and female (Pierce, 1993; Schotborgh, 2005). After hatching the chick is brooded and fed on regurgitated 'crop milk' (Clout, 1990). Chicks fledge between 40-45 days after hatching and continue to be fed by the father for approximately a week after fledging (Clout, 1990).

1.1.3 Diet

Kereru are generalist feeders, preferring fruit of native and introduced species when it is available but supplementing their diet with foliage and flowers of native and introduced species. Kereru have key food species on which they focus feeding at different times of the year (Bell, 1996; Clout *et al.*, 1986; Clout *et al.*, 1991; Hill, 2003; Lyall, unpublished; McEwan, 1978; Pierce & Graham, 1995; Ridley, 1998; Schotborgh, 2005). Loose flocks of a few to 100+ kereru can be seen feeding on highly preferred and abundant food sources (Higgins & Davies, 1996). Switching between foods is not always related to food availability, with less common or locally confined species being sought out even when other widely-available species are available. For example, Ridley (1998) found that pate (*Schefflera digitata*) fruit was highly selected for by kereru in autumn - even though pate made up only 0.9% of the total basal area of vegetation in the study area. Seven other species were eaten during this time but none were selected for (Ridley, 1998).

Kereru in Northland forests eat mainly fruit year-round but supplement their diet with foliage and flowers (Pierce, 1993; Pierce & Graham, 1995). Large-fruited plant species such as tawa (*Beilschmiedia tawa*), taraire (*Beilschmiedia taraire*), karaka and puriri (*Vitex lucens*) are common in these forests, and where available comprise a large proportion of the kereru diet (Bell, 1996; Dijkgraaf, 2002; Hill, 2003; Pierce, 1993; Pierce & Graham, 1995). New Zealand

forests in regions south of Auckland have predominately temperate characteristics, with fewer large-fruited tree species and restricted fruit availability over winter and spring (Dijkgraaf, 2002). Kereru diets become increasingly less dependant on native fruit with increasing latitude (Bakken & Lee, 1992; Clout, 1990; Dunn, 1981; J. Lyall, *pers. comm.*; Schotborgh, 2005). The proportion of native and introduced species and food types found in the kereru diet varies with local availability and regional changes in forest composition.

It appears that foods are selected for their nutritional value, especially sugar, lipid and protein content, depending on energy requirements which vary between breeding and non-breeding seasons (Dijkgraaf, 2002; Hill, 2003). Large fruits are selected because they provide the maximum nutrition for minimum energy expended feeding (Hill, 2003). For the same reason clustered fruit is preferred to small solitary fruit (Hill, 2003). Hill (2003) and Schotborgh (2005) suggested that in the absence of fruit high in protein, protein-rich foliage of native and introduced legumes and new leaves of deciduous species are selected for prior to the breeding season.

1.1.4 Home range and movements

Home range size and movements by kereru are directly linked to availability and distribution of foods (Bell, 1996; Clout *et al.*, 1986; Clout *et al.*, 1991; Hill, 2003; Pierce & Graham, 1995; Schotborgh, 2005). Adult kereru tend to be sedentary in areas containing year-round food supplies (Mander *et al.*, 1998). Bell (1996) found that home ranges of adult kereru in Wenderholm Regional Park ranged between 20 and 30 ha; core areas were 1-2 ha in size. Kereru in the Lyttelton Harbour area, Banks Peninsula, occupied home ranges of 2 – 22 ha with core areas of less than 0.5 ha in size (Schotborgh, 2005). Bell (1996) found that juvenile kereru had much larger home ranges than adults.

At other sites kereru may move between a number of traditional seasonal home ranges (Clout *et al.* 1991; Hill, 2003). Clout *et al.* (1991) found kereru in Pelorus Bridge Scenic Reserve, Nelson moved up to 18-20 km to other areas of native forest. Hill (2003) found that kereru in Whirinaki Forest Park, central North Island, moved up to 24 km; many of these movements were between forest types. While home ranges of these kereru were relatively large (mean=163 ha), core areas within home ranges were approximately 6% of the total home range size (Hill, 2003).

1.1.5 Role in forest regeneration

Around 70% of native woody plants in New Zealand bear fruit suitable for vertebrate dispersal (Clout & Hay, 1989; Dijkgraaf, 2002; Schotborgh, 2005). There have never been any medium or large mammals capable of dispersing large (>12 mm in diameter) fruits (Dijkgraaf, 2002). Consequently the regeneration process for these species is closely linked with the consumption of fruits and defecation of seeds by frugivorous birds. Depletion of native seed-dispersing bird species by predation and habitat loss has threatened effective regeneration of mixed forests in New Zealand (Burrows, 1994). Some fruit-eating birds once common in lowland forest and capable of dispersing large-seeded species were huia (*Heteralocha acutirostris*), piopio (*Turnagra tanagra*; *T. capensis*), finsch's duck (*Euryanas finschi*) and kokako (*Callaeas wilsoni*; *C. cinera*) (Wilson, 2004).

Kereru are now virtually the only native bird species capable of swallowing and dispersing seeds between 12 and 25 mm in diameter (Clout & Hay, 1989; Gibb, 1970). Because kereru can be highly mobile they have the potential to move seeds away from the parent tree and into environments where the seedlings have a higher chance of survival (Bell, 1996; Clout & Tilley, 1992). Trees such as miro (*Prumnopitys ferruginea*), tawa, taraire, puriri and karaka rely almost entirely on kereru for dispersal (Bell, 1996; Clout, 1990; Dijkgraaf, 2002; McEwan, 1978). Extensive fragmentation of native forest poses a problem for native plant species that produce fleshy fruit. Some of these species are restricted to small remnants of forest and require frugivores to facilitate the movement of seeds to other forest remnants (Wilson, 2004). While some introduced birds such as blackbirds (*Turdus merula*) and song thrush (*Turdus philomelos*) disperse the seeds of small-fruited native species (Williams & Karl, 1996), large-fruited species may be threatened by the decline in potential dispersers.

1.2 Justification for the research

Kereru are widespread but are in serious decline in many areas of New Zealand (Heather & Robertson, 2005). Kereru were extensively hunted by Maori and later European settlers (Clout, 1990) who decimated populations throughout New Zealand. Added pressure came in the form of habitat destruction by forest clearance, predation by introduced mammals such as mustelids (*Mustela* spp.), cats (*Felis catus*) and rats (*Rattus* spp.) and competition for food and nest predation by brush-tailed possums (*Trichosurus vulpecula*). Consequently kereru are far less abundant and more restricted in distribution than they once were.

The Department of Conservation (DOC) considers the implementation of a kereru monitoring and management strategy to be important (Mander *et al.*, 1998). Mander *et al.* (1998) suggested kereru populations need to be monitored because:

- The kereru is a keystone species vital to the wellbeing of New Zealand forests.
- Kereru are at risk of becoming endangered because of their low reproduction rate and vulnerability to introduced predators.
- More quantitative data is needed to confirm why kereru populations are declining and how rapidly.
- More quantitative data is needed to resolve the issue of whether customary use by Maori is viable.

In response to these concerns DOC established the National Kereru Monitoring Programme, the first step in the development of a national kereru conservation strategy (Mander *et al.*, 1998). DOC actively encourages iwi and community-based projects such as the Kaupapa Kereru Programme.

The Kaupapa Kereru Programme (KKP) was established in 2000 after Ngāi Tahu kaumātua expressed a desire to increase kereru numbers on Banks Peninsula. KKP is co-ordinated by Craig Pauling of Te Rūnanga o Ngāi Tahu and consists of a committee with representatives from four Banks Peninsula Papatipu Rūnaka, Lincoln University; Manaaki Whenua; Department of Conservation and the Banks Peninsula Conservation Trust.

The principal aim of KKP is to increase the kereru population on Banks Peninsula. To achieve their goal KKP have used two distinct approaches:

- 1) Research into the ecology of kereru to gain an understanding of movements, vegetation use and feeding requirements as well as identifying predators of concern.
- 2) Community education to raise awareness about the importance of kereru to both people and the forest ecosystem of Banks Peninsula and to develop working relationships with the community.

Increasing the kereru population on Banks Peninsula will have ecological and cultural benefits. Regeneration of native forest will benefit from increased seed dispersal by kereru. Increasing the amount of quality habitat and controlling pest species on Banks Peninsula will also benefit many other plant and animal species. Kereru are a taonga (treasure) species of cultural and spiritual significance to Maori and are an iconic species to New Zealanders as a whole.

Kereru is an animal that the general public feel emotive towards and would like to preserve for future generations.

With the improvement of radio-tracking equipment in the last decade it is now possible to collect data with a high level of precision. Studies on various aspects of kereru ecology have been carried out using radio-tagged kereru in large tracts of native forest (Clout *et al.*, 1986; Clout *et al.*, 1991; Hill, 2003), areas of fragmented native forest (Bell, 1996; Clout *et al.*, 1995) and urban-rural habitats (Pierce & Graham, 1995; Prendergast, 2006; Schotborgh, 2005).

Two comprehensive studies of kereru ecology have been completed in the rural-urban landscape on Banks Peninsula as part of the KKP (Prendergast, 2006; Schotborgh, 2005). These studies were conducted in a highly modified landscape that contained little native forest. Fragments of suitable kereru habitat were small and were surrounded by large areas of poor quality habitat such as pasture. Schotborgh (2005) investigated home ranges, movement, diet and breeding of kereru at two study sites in the Lyttelton Harbour area. The Orton Bradley Park study site was a farm park used for recreational and farming activities and the Church Bay study site was a small residential area surrounded by farmland. Both study sites contained small fragments of regenerating native forest. Nothing is known about kereru ecology in areas on Banks Peninsula that contain large (>100 ha) areas of regenerating native forest. The aim of this study was to build on previous studies by investigating home ranges, diet and use of vegetation communities over a 12-month period by kereru captured in Hinewai Reserve, the largest native forest fragment on Banks Peninsula.

1.3 Objectives

Objectives of this study were:

- 1 To determine annual and seasonal home ranges of kereru, and to identify changes between seasonal home ranges.
- 2 To determine the extent and frequency of movements made by kereru.
- 3 To describe vegetation communities which are used by kereru and to determine if there is selection for or against particular vegetation communities.
- 4 To describe seasonal use of food species by kereru and determine how diet relates to phenology of key food species.

Detailed information about the Hinewai Reserve and Akaroa study sites can be found in Chapter 2. Capture and radio-tracking methodology are covered in detail in Chapter 3. Chapter 4 describes the phenological pattern of 11 plant species predicted to be key foods for kereru in Hinewai Reserve. Plant species and plant parts eaten by kereru throughout the study period are described in Chapter 5. Home ranges and movements of kereru are presented in Chapter 6; Chapter 7 investigates habitat use within home ranges. Chapter 8 discusses key findings of the present study and suggests strategies to enhance kereru numbers and range. Recommended topics for future research on kereru are also given. Scientific names of plant species eaten by kereru in this study can be found in Appendix 4. All other scientific names of plants and animals are given with the first mention of common names.

Incidental observations regarding the breeding biology of tagged kereru were made during this study. Notes on the timing of nesting, number of nesting attempts made by each pair and nest fate are included in Appendix 7.

Chapter 2

Description of study sites

2.1 Characteristics of the Banks Peninsula landscape

Banks Peninsula is a highly-modified landscape in which indigenous biodiversity has been significantly reduced. The current setting is a mosaic of farmland, small urban centres and small native forest fragments. Fire, farming and timber milling stripped the area almost bare of native vegetation. Old growth forest was reduced to <1% of the total land area by the early 1900's and remnants are very small and widely separated from each other (Wilson, 1993, 1994, 1995). Currently a much larger proportion of the peninsula is covered in native forest due mostly to regeneration in gullies and restoration projects. Regenerating vegetation is mostly second-growth kanuka or mixed-hardwood forest comprised of species such as fuchsia (*Fuchsia exorticata*), kowhai (*Sophora microphylla*), mahoe (*Melicytus ramiflorus*), lemonwood (*Pittosporum eugenioides*), lacebark (*Hoheria augustifolia*), five finger (*Pseudopanax aboreas*), broadleaf (*Griselinia littoralis*) and ribbonwood (*Plagianthus betulinus*) (Wilson, 1993). These vegetation types are typically not valued by farmers and often are cleared or sprayed to make way for pasture.

Habitat loss and introduced mammalian predators and browsers have impacted heavily on the birds of Banks Peninsula. Kereru numbers declined dramatically after human settlement but the species appears to have adapted well to the modern landscape, relying heavily on introduced food species for some parts of the year (Schotborgh, 2005; Wilson, 2004). Anecdotal accounts suggest that kereru populations are increasing in some parts of the peninsula (Allen, in prep).

2.2 Descriptions and history of study sites

Hinewai Reserve was intended to be the only site on which kereru would be studied (Fig. 2.1). However, three of the kereru captured at Purple Peak Saddle, in Hinewai Reserve, proved to be birds normally resident in Akaroa. Thus a second urban-rural study site (Akaroa) was added to the study (Fig. 2.1). Two discrete groups of tagged kereru were identified within the Hinewai

Reserve study site: kereru that spent most of their time in the vicinity of Purple Peak Saddle and those that spent most of their time in the lower half of Otanerito Valley and Sleepy Bay gully.

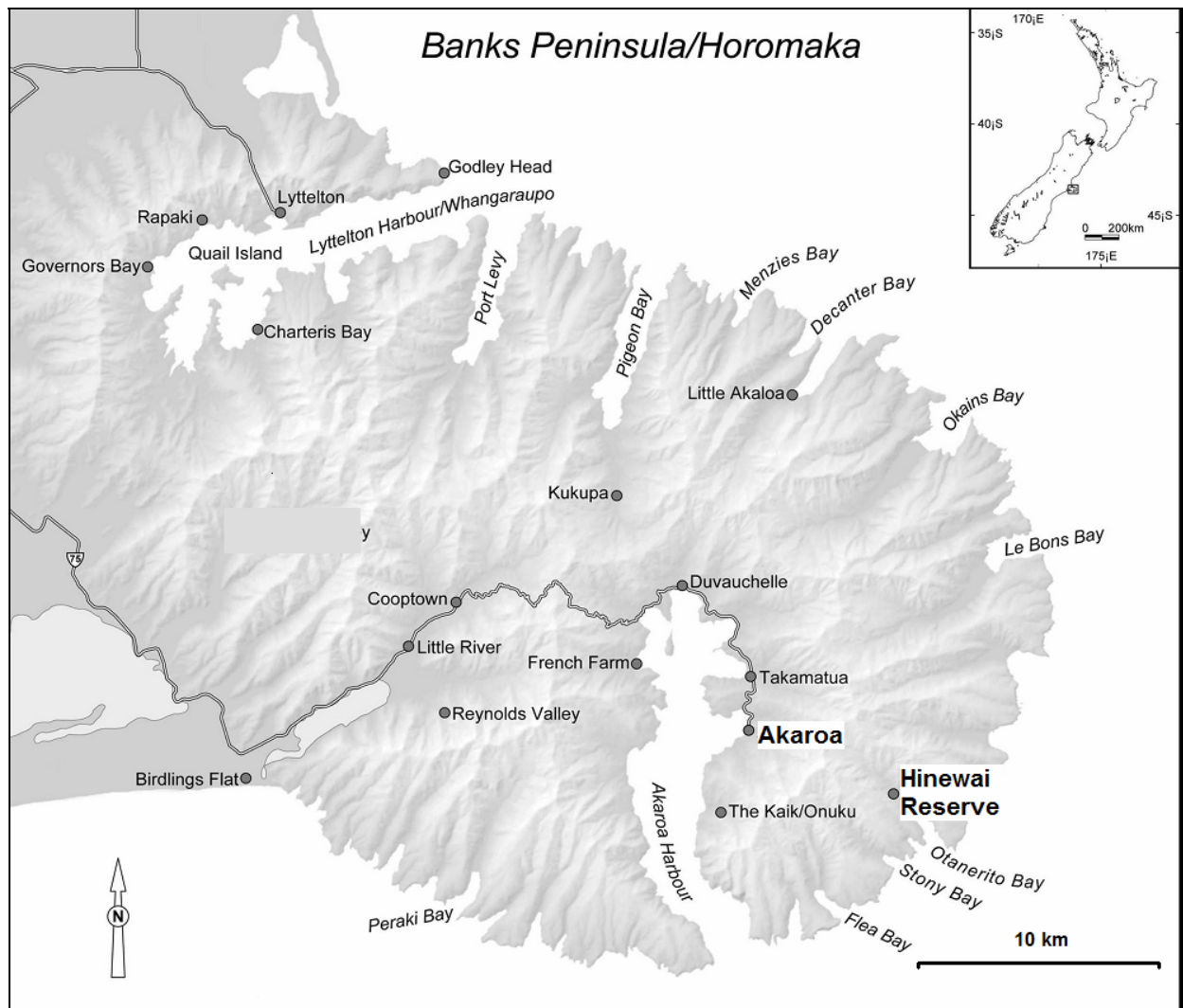


Figure 2.1. Map showing Banks Peninsula and locations of Akaroa Township and Hinewai Reserve (adapted from: Allen, in prep).

2.2.1 Hinewai Reserve study site (including lower Otanerito Valley and Sleepy Bay gully)

Hinewai Reserve is a privately-managed reserve that occupies most of Otanerito Valley, part of Stony Bay gully and the upper bluffs of Stony Bay Peak overlooking Akaroa (Fig. 2.3). The reserve was purchased by the Maurice White Native Forest Trust in 1987. Initially it was only 109 ha, but in 1991 the reserve was expanded to its current size of 1050 ha when neighbouring Otanerito Station was purchased by the Forest Heritage Fund (Wilson, 1995). Hinewai is managed by botanist and naturalist Hugh Wilson who lives full time on the reserve.

There is a steep gradient from the top of Stony Bay Peak, at 806 m above sea level, to the bottom of the reserve, which is only 20 m above sea level (Wilson, 1994) (Fig. 2.2). There are corresponding gradients of rainfall and temperature and also dramatic changes in forest composition from high to low altitude.

At the time of purchase most of Hinewai was pasture interspersed with gorse and broom. Approximately 4% of the reserve is covered by old growth forest occupying land that escaped fire during Polynesian settlement and conversion to pasture by European settlers (Wilson, 1993). A large proportion of this is beech forest, dominated by red beech (*Nothofagus fusca*) and Hall's totara (*Podocarpus hallii*), which occurs in small patches on the fertile upper reaches of Otanerito and Stony Bay valleys (Wilson, 1994). The rest is comprised of scattered remnants of podocarp-hardwood forest dominated by kahikatea (*Dacrycarpus dacrydioides*), matai (*Prumnopitys taxifolia*) and totara (*Podocarpus totara*), which formerly occupied all of the reserve below c. 300 m (Wilson, 1994). The major vegetation type is gorse (*Ulex europaeus*) and broom (*Cytisus scoparius*) scrub followed by second-growth hardwood forest and kanuka scrub.

Gorse, broom and kanuka act as a nurse crop for regenerating native forest with minimum interference. Shade tolerant species such as mahoe, fuchsia, pate, *Pseudopanax spp.*, wineberry (*Aristotelia serrata*) and lemonwood have regenerated under gorse, broom and kanuka. Podocarps such as Hall's totara, kahikatea and matai also show substantial regeneration (Wilson, 1994). Currently a considerable proportion of the reserve is covered with native vegetation of some sort.

Possums, stoats (*Mustela erminea*), ferrets (*Mustela furo*) and feral cats are all common predators in and around Otanerito Valley but it is not known to what extent these predators impact on bird populations within the Hinewai Reserve study site (H. D. Wilson, B. Narbey; F. Farrell, *pers. comm.*).

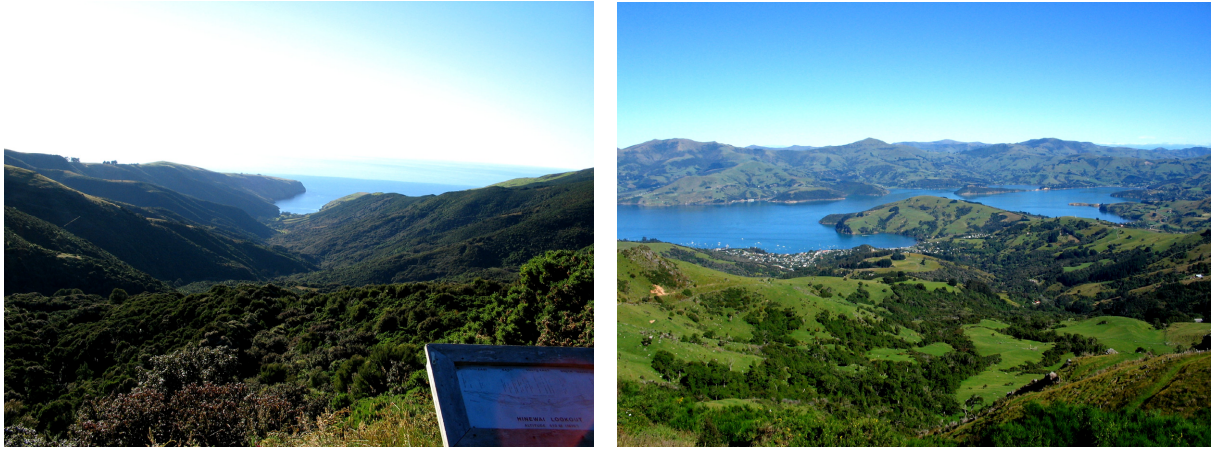


Figure 2.2. Photo of Hinewai Reserve and lower Otanerito Valley (left) and Akaroa Harbour and Township (right).

2.2.1.1. Purple Peak Saddle

Vegetation composition in this area of Otanerito Valley is quite different to that in the lower valley. The dominant canopy species near the saddle are ribbonwood and kowhai; fuchsia and horopito are the main sub-canopy species (pers. obs.). Broadleaf and Hall's totara are also common (pers. obs.). Broom is prolific in open spaces as is horopito and patches of these species are interspersed by pasture (pers. obs.) A large fragment of beech forest lies adjacent to this area (pers. obs.).

2.2.1.2 Lower Otanerito valley and Sleepy Bay gully

Most of the lower Otanerito Valley and adjacent Sleepy Bay gully is not part of Hinewai Reserve. This area of the study site is mostly farmland with two small plots of macrocarper (*Cupressus macrocarpa*), pine (*Pinus radiata*) and eucalypt (*Eucalyptus leucoxylon*) forest and small fragments of native forest and scrub (pers. obs.). Native forest in this part of the study site is confined to gullies where the understory is eaten out by stock. Species composition in these gullies is similar to that in Hinewai Reserve but species diversity is more limited due to the lack of understory. The dominant canopy species are rohutu (*Lophomyrtus obcordata*), mahoe and pigeonwood (*Hedycarya arborea*) in the coastal gullies and mahoe and kanuka in Sleepy Bay gully (pers. obs.).

2.2.2 Akaroa study site (Akaroa township and surrounding farmland).

Humans have settled the Akaroa region for around 800 years. Initial settlement began with Polynesian hunter-gathers who subsisted on native flora and fauna as well as the Polynesian dog (kuri, *Canis familiaris*) and rat (kiore, *Rattus exulans*) (McCulloch, 1987). Their Maori descendants were the first to cultivate crops and clear land by fire (McCulloch, 1987; Wilson,

1993). European settlement began in the early 19th century in the form of the whaling and flax (*Phormium tenax*) trading industries (Pawson, 1987). The township itself was not formed until 1840 when 63 French colonists, and later an English magistrate and his staff, settled as smallholders on five acre blocks (Pawson, 1987). Wide scale British colonisation began in the early 1840's but until 1872 the only route to Akaroa was by sea (Pawson, 1987).

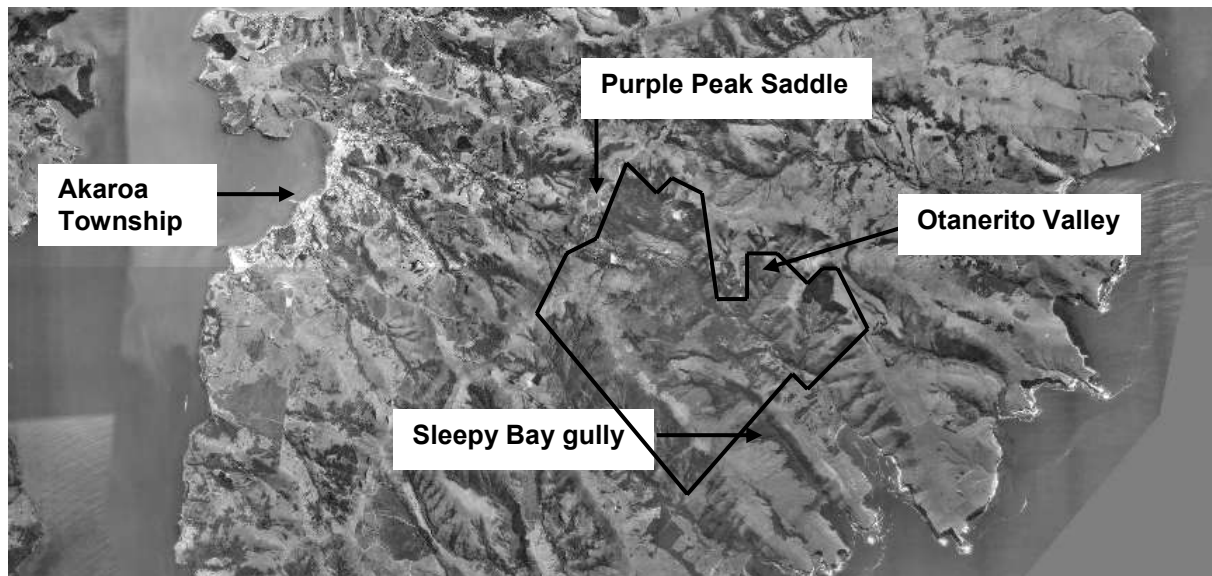


Figure 2.3. Aerial photo of the southeast corner of Banks Peninsula showing a rough outline of Hinewai Reserve and highlighting important areas within the study sites.

Because the district is so close to Christchurch it has been a popular holiday spot for well over a century (Pawson, 1987). Today tourism is the towns' major industry attracting large numbers of international and national tourists, especially over the summer months. Akaroa's colonial past is reflected by a wide range of introduced plant species in gardens, along roadsides and on farmland. Tree lucerne (*Chamaecytisus palmensis*) is much more common here than in Otanerito valley, however in some parts of the township this species is being removed. Broom is less common; patches tend to be small and scattered.

Akaroa has also retained quite a few small native forest fragments in and around the township (Fig. 2.2). The value of retaining and planting native vegetation has been recognised by many property owners. The range of native species available to Akaroa kereru is similar to the Hinewai Reserve study site but there are some differences. There is little well-developed coastal forest or scrub around the Akaroa study site and most native forest fragments are grazed by stock. Many fragments also contain introduced tree and weed species such as oak (*Quercus spp.*) and hawthorn (*Crataegus oxycantha*). Chapter 3 describes methodology used for capture and radio-tagging of kereru and data collection.

Chapter 3

Capture and radio tagging of kereru

3.1 Capture of kereru

Capture, radio-tagging and collection of feather samples was approved by the Department of Conservation (DOC: Low Impact, Collecting and Research Application, National Permit Number: CA-15590-RES, www.doc.govt.nz) and by the Lincoln University Animal Ethics Committee (Application Number: 67).

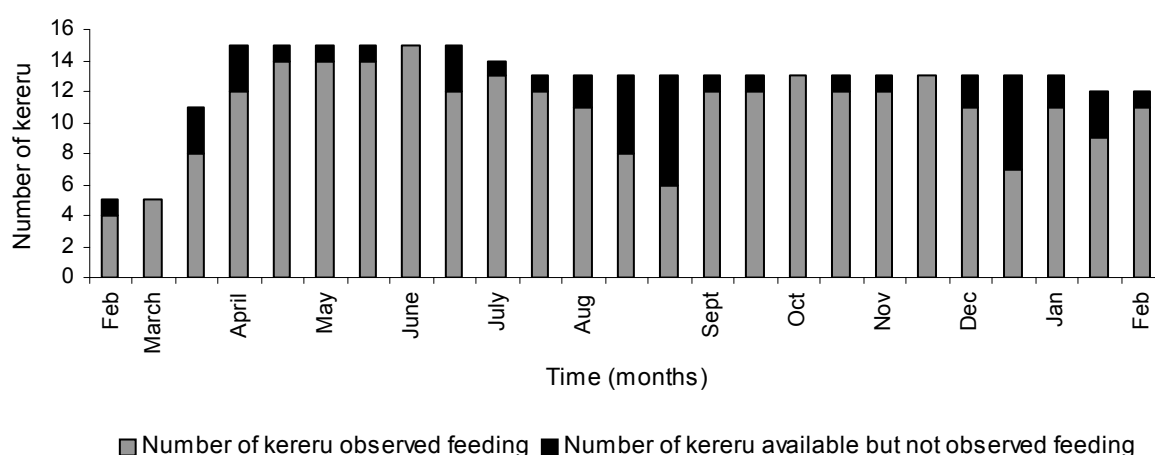


Figure 3.1. Number of kereru available for data collection in all areas.

A total of fifteen adult kereru were caught in Hinewai Reserve. Capture of kereru was staggered over February, March and April 2005 (Fig. 3.1). After the full 15 kereru had been caught, two kereru died in July. In January one kereru #66 usually resident in Akaroa could not be found in the study area or surrounding areas. The number of kereru available for data collection varied from five to 15 (Fig 3.1).

Keruru were captured in mist nets with a mesh size of 10 cm. Mist nests were mounted on 7-m aluminium poles stabilised by guy ropes and set up in kereru flight paths between roosting and foraging sites (Fig 3.3A). Experienced Department of Conservation staff and Lincoln University personnel assisted with assembly of mist nets and capture and handling of kereru.

3.1.1 Capture sites

Kereru regularly flock together at Hinewai Reserve to feed on the fruit of poroporo and horopito (H. D. Wilson, *pers. comm.*). Kereru activity in areas where large numbers of these species grew was monitored in the month before capture. Flight paths suitable for the erection of mist nets were determined by watching kereru. Suitable flight paths were those that were used regularly by several kereru and were low enough for kereru to fly into the mist nets (<7 m). Both suitable capture sites were near the reserve boundary. Nine kereru were captured while feeding on poroporo (*Solanum aviculare*; *S. laciniatum*) around Otanerito Homestead in lower Otanerito Valley (Fig 3.2). Six kereru were captured while feeding on horopito in upper Otanerito Valley near Purple Peak Saddle (Fig 3.2). Two kereru at the Otanerito Homestead site (# 60 and # 58) were inadvertently recaptured once. Frequencies; sex (if known); dates of capture; catch sites and areas of residency are shown for individual kereru in Appendix 1.

3.2 Fitting of radio transmitters and leg jesses

Kereru were removed from the mist nets, placed in a lightweight cotton bag and weighed using a handheld pesola (1000 g). Plumage, eye, beak and leg colour of each kereru were inspected to determine whether kereru were adults or juveniles. Each kereru was fitted with a radio transmitter and banded using individually numbered S or K bands. Banding of kereru was carried out on Kerry-Jayne Wilson's existing kereru banding permit number (0298). A uniquely coloured leg jess (colour identification tag) or combination of two leg jesses were attached to the leg(s) of each kereru to allow for visual identification of individuals (Fig 3.4). The design of these jesses is identical to those used by DOC scientists in previous kereru studies. Jesses were made of PVC-coated nylon and were about 2 cm wide and 10 cm long (Schotborgh, 2005). Three contour feathers were removed from each bird to allow sexing of kereru using DNA at a later stage.

Transmitters were SIRTrack Ltd ® (Havelock North, NZ, www.sirtrack.com) units; each operated on a unique frequency and emitted a pulsed signal (40 pulses per min). Transmitter plus harness weighed approximately 20 g and had a battery life of 14 months. Transmitters were mounted using weak-link harnesses, which held the transmitter in place on the back of the kereru (Fig 3.3 B) (Karl & Clout, 1987). The harnesses were made from a soft-braided nylon cord and had a 'weak link' mechanism, which consisted of a piece of linen thread covered with a plastic sleeve. If sufficient pressure is applied the thread breaks and releases the kereru from the harness. This means that kereru were able to get free if the harness snagged in a tree; with

time the weak link should rot and release the kereru from the harness (Karl & Clout, 1987). The harness was crafted in a way that ensured it would not chafe the bird. Kereru fitted with radio transmitters will hereon be referred to as ‘tagged kereru’, kereru without transmitters will be referred to as ‘untagged kereru’.

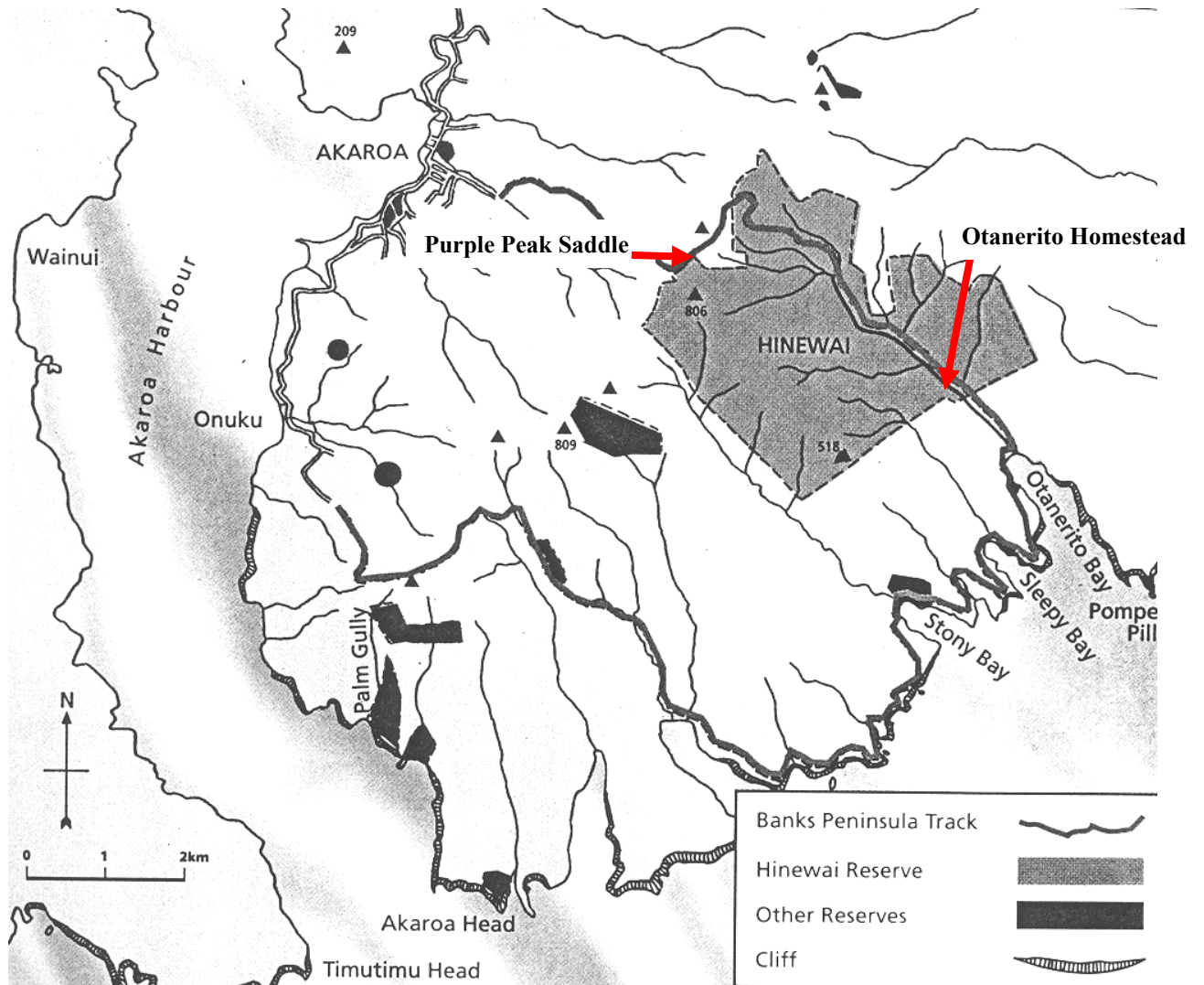


Figure 3.2. Map of the wider Akaroa area showing Hinewai Reserve and locations of the Otanerito Homestead and Purple Peak Saddle capture sites (adapted from Wilson, 1995).

A



B



Figure 3.3. A) Mist nets were set up between feeding and resting sites (Peter Dilks of DOC in the foreground, photo: T. Greene). B) kereru with a partially-fitted nylon harness and transmitter.

Once processed, kereru were released at the capture site. Time from capture to release for each kereru was between 20-30 minutes. No kereru were injured during capture and each of the birds flew away into nearby vegetation without difficulty. Each kereru was monitored for several hours after release and checked again the following day. Directly after release kereru spent several hours perched in the same position but showed no signs of undue stress (eg. panting) and had resumed normal activity by the following day. Information (band number, jesse(s) colour, weight, transmitter frequency and, if carried out, the results of DNA analysis) gathered during capture will be added to the DOC national kereru database.



Figure 3.4. Radio-tagged kereru with a yellow leg jess clearly visible (photo: K-J Wilson).

3.3 Radio tracking of kereru

The transmitters were on a cycle of 12 hours on/12 hours off so that they gave maximum daylight tracking potential. This was 7am-7pm in New Zealand daylight savings time and 6am-6pm in New Zealand standard time. Kereru were tracked from February 2005 to February 2006 (26 field trips). Field weeks were five days in length and took place in alternate weeks. Tagged kereru were tracked on foot from the closest point accessible by vehicle. A hand-held Yagi antennae and Regal 1000 radio-receiver (Alana Ecology, Shropshire, UK, www.alanaecology.com) were used to track kereru.

Lack of independence between location fixes (autocorrelation) can cause home range size to be underestimated (Swihart & Slade, 1985; Walsh, 2002). Bell (1996) and Schotborgh (2005) both indicated that a minimum of two hours is a suitable time period between location fixes for kereru. It is presumed that this gives kereru time to move to any location within its home range between fixes. I attempted to locate each kereru one or two times a day during each field week. Due to time constraints, location fixes of kereru were always more than two hours apart presumably negating the issue of statistical independence.

Due to daily time constraints, kereru known to be in the same area were located consecutively. The order in which areas were visited was changed daily. The order in which kereru were located within each area was also changed daily to try and minimise bias caused by regularly locating kereru at the same time of day.

Once a tagged kereru was located with telemetry equipment I attempted to locate the bird visually. When possible, the location of each kereru was recorded using a handheld GPS unit. If a kereru was hidden in the canopy, a GPS fix was taken from the point of the strongest signal. On occasion a GPS fix was impossible to get, so instead an estimate of the location of the kereru was obtained. Estimates were acquired in one of three ways:

1. When clear sky was obscured by overhead vegetation or heavy cloud it was not always possible to obtain a GPS fix at the exact location of a kereru. Instead, a GPS fix was taken from the closest point possible. A distance estimate and bearing of the position of the kereru was taken from this fix and used to plot the position of the kereru in ArcMap™ (ArcGIS 9) (Minami *et al.*, 1994-2004).

2. When I physically could not reach the kereru but could track the location of the kereru to a small area of homogenous vegetation, I placed the location point in the centre of that area.

3. When I physically could not reach the kereru and it was not possible to pinpoint the patch of vegetation the kereru was in, I estimated the location by triangulation from known points fixed using GPS as in Kenward (2001).

When kereru # 66 could not be located for more than 2 consecutive days a search was carried out from high vantage points. This involved scanning for the missing kereru from points around the study area that had good line-of-sight views of Akaroa and adjacent valleys. Kereru # 66 was searched for in every subsequent field week until the end of the study period.

For each kereru, GPS co-ordinates obtained in each field week were entered into a Microsoft Excel spreadsheet and imported into ArcMap™. Co-ordinates for each field week were plotted onto a digital photograph of the study area in order to visually assess them.

3.3.1 Observations of tagged kereru

Observations were made every time a radio tagged kereru was sighted. The position and activity of each kereru was recorded in a similar manner to Pearson & Climo (1993). Observations of each kereru were made continuously for 15-30 minutes. Observations included: time of observation, activity, tree species, perch type, forest stratum, height of kereru above the ground, canopy height and the number of untagged kereru present in the vicinity. The length of each observation was not consistent because time constraints meant that priority had to be given to collecting sufficient location data for home range analysis. Feeding data was the next priority and other activities were considered less important. If a kereru fed in the first 15 minutes of an observation period, that individual was observed for the minimum time. If no feeding activity occurred in the first 15 minutes, the individual was observed for the full 30 minutes. Activities recorded included the following:

- Roost: to perch or settle to rest
- Fly
- Feed: to take and swallow food
- Preen: maintenance of feathers
- Nest: to sit on an egg
- Nest building: to gather twigs or construct nest

- Display: to perform a display flight
- Chase: to chase other kereru away from a food source

Each activity was recorded only once in each observation period i.e. if a bird was feeding then spent time preening and afterwards went to back to feeding on the same food, this was counted as only one feeding event. Care was taken to disturb kereru as little as possible during observations. Observations were recorded on a pre-prepared datasheet (Appendix 2). The number of observation periods for each kereru throughout the year is shown in Appendix 1.

Chapter 4

Phenology

4.1 Introduction

Precipitous change in altitude and proximity to the ocean affect phenological patterns within Hinewai Reserve. These features create microclimates within the reserve, which in turn influence phenology. Hugh Wilson, manager of Hinewai Reserve, has observed a lag in phenological events of around two weeks between individuals of the same species close to sea level and individuals at high altitude (400-800 m) (*pers. comm.*). Phenological events are also likely to be influenced by the fragmented nature of forest within the reserve (Bach, 2002). Native forest on the reserve consists of several large fragments and adjoining smaller fragments. Consequently there are more forest margins and forest gaps than would occur in a continuous tract of forest. Forest gaps are described as 'keystone habitats' because plants within gaps will exhibit extended fruiting periods and larger crops of fruit due to variation in microclimates (Bach, 2002; Hill, 2003). Keystone habitats are considered vital for supporting fruit-eating animals, especially during times of food shortage (Hill, 2003).

Kereru exhibit apparent preferences for certain plant species and plant parts when they are available. An assumption is that preferred foods and plant parts are relatively high in nutritional value and necessary to meet nutritional requirements. Therefore these species must be of higher importance for sustaining kereru populations. It is likely that relative importance of individual species to kereru populations varies within and between sites depending on forest composition and times of availability for each species. It is necessary to determine how the availability of key food species changes throughout the year and how this may effect diet composition.

The aim of this chapter is to assess the pattern of food availability within Hinewai Reserve over a 13-month period using a subset of native and exotic species selected for their prominence as key food species at similar sites. Times of the year when peaks of leaf flush and fruiting occur within the reserve will be determined. This information will be used in subsequent chapters to determine the influence of food availability on diet and movement patterns of kereru.

4.2 Methodology

4.2.1 Selection of monitored individuals

Because time and labour constraints excluded the possibility of monitoring all known kereru food plants on the reserve, 11 plant species predicted to be key food species within Hinewai Reserve were chosen for phenology monitoring. Species known to be eaten by kereru in Hinewai Reserve and elsewhere on Banks Peninsula were selected (H. D. Wilson, *pers. comm.*; J. Lyall, *pers. comm.*; Schotborgh, 2005). This subset of species was intended to provide a generalised view of the timing of phenological events within the reserve and how these events are linked to kereru feeding and movement.

Native species selected for monitoring were: mahoe, kowhai, pate, horopito (*Pseudowintera colorata*), ngaio (*Myoporum laetum*), poroporo, fuchsia, wineberry and kaikomako (*Pennantia corymbosa*). Introduced species selected were tree lucerne and broom. As with Hill (2003) it was thought necessary to only monitor plant parts known to be eaten by kereru for each species. Pate, horopito, ngaio, poroporo, wineberry and kaikomako were monitored for fruit abundance alone. Fuchsia was monitored for fruit and flower abundance and mahoe for fruit and foliage abundance. Kowhai, broom and tree lucerne were monitored for foliage and flower abundance.

With the exception of tree lucerne, all the food species selected for phenology monitoring were abundant or fairly common within the reserve (H. D. Wilson, *pers. comm.*). However, most species were not distributed evenly over the whole reserve, a factor that influenced the design of sampling methods. Tree lucerne occurred in only three patches and kowhai, poroporo, ngaio, horopito and broom were all localised to some extent (*pers. obs.*).

A minimum of 12 and maximum of 18 individuals of each species were monitored. A set of random co-ordinates, which were within the boundaries of Hinewai Reserve, was generated. Nine 150-m line transects were placed at the closest points accessible by foot (e.g. close to tracks) to the first nine co-ordinates selected from the set. In some cases transects crossed tracks but did not run along tracks. The first individuals of each species that A) had a basal measurement of >12 cm at waist level, and B) that were low enough so that the majority of the canopy could be seen, were selected for monitoring along each transect. Because of differences in forest composition, not all selected species occurred in all transects. For species

that did not have at least 12 individuals included in transects, several random grid co-ordinates were assigned and the nearest accessible individuals to the co-ordinates were sampled.

4.2.2 Data collection

Only healthy individuals of each tree species that showed no obvious signs of disease, nutrient deficiency or severe herbivory were selected. Individuals were mature (basal measurement at waist level >12 cm). As the forest in the reserve was young and none of the monitored species reach a height greater than c. 15 m (Poole & Adams, 1994), this did not result in bias against tall trees. Each selected plant was marked with flagging tape and mapped so they could be easily located.

Phenology monitoring of each individual was done once every second week from the 20th of February 2005 to the 28th of February 2006. A simple factorial system that could be applied to all species was used. Fruit, flower and leaf abundance were ranked as follows: 3=very abundant, 2=moderate abundance, 1=scarce, 0=absent. Abundance was evaluated visually by estimating the proportion of the crown covered. Assessment of abundance was altered accordingly for each species i.e. fuchsia carries less fruit at peak production than mahoe. High levels of irradiance are known to enhance flower and fruit production (Dijkgraaf, 2002, Laurance *et al.*, 1998). I was able to get an idea of what a ‘very abundant’ fruit crop looked like for each species by observing un-monitored individuals in full sun. A smaller number of categories was used than in previous phenology studies of kereru food species: Pierce and Graham (1995) used 10 and Hill (2003) used 5. But as suggested by Hugh Wilson (*pers. comm.*) it is such a subjective process that splitting categories up further would not give information of greater accuracy.

The same ranking was used separately for ripe and unripe fruit. Fruit was classified as ripe if it was judged to be close to the colour recorded in Poole and Adams (1994). Any other colours were classified as unripe. Vegetative growth was classified as being new growth - light green and soft in texture as well developed leaf buds, or mature growth – dark green and firmer in texture.

I noted evidence of browsing when it was obvious, but data specific to browsing was not collected and therefore does not appear in the results. However, possible causes of browsing are discussed. Data collected from phenology monitoring was used to help interpret the feeding and movement patterns described in later chapters.

4.3 Results

4.3.1 Phenology of all species

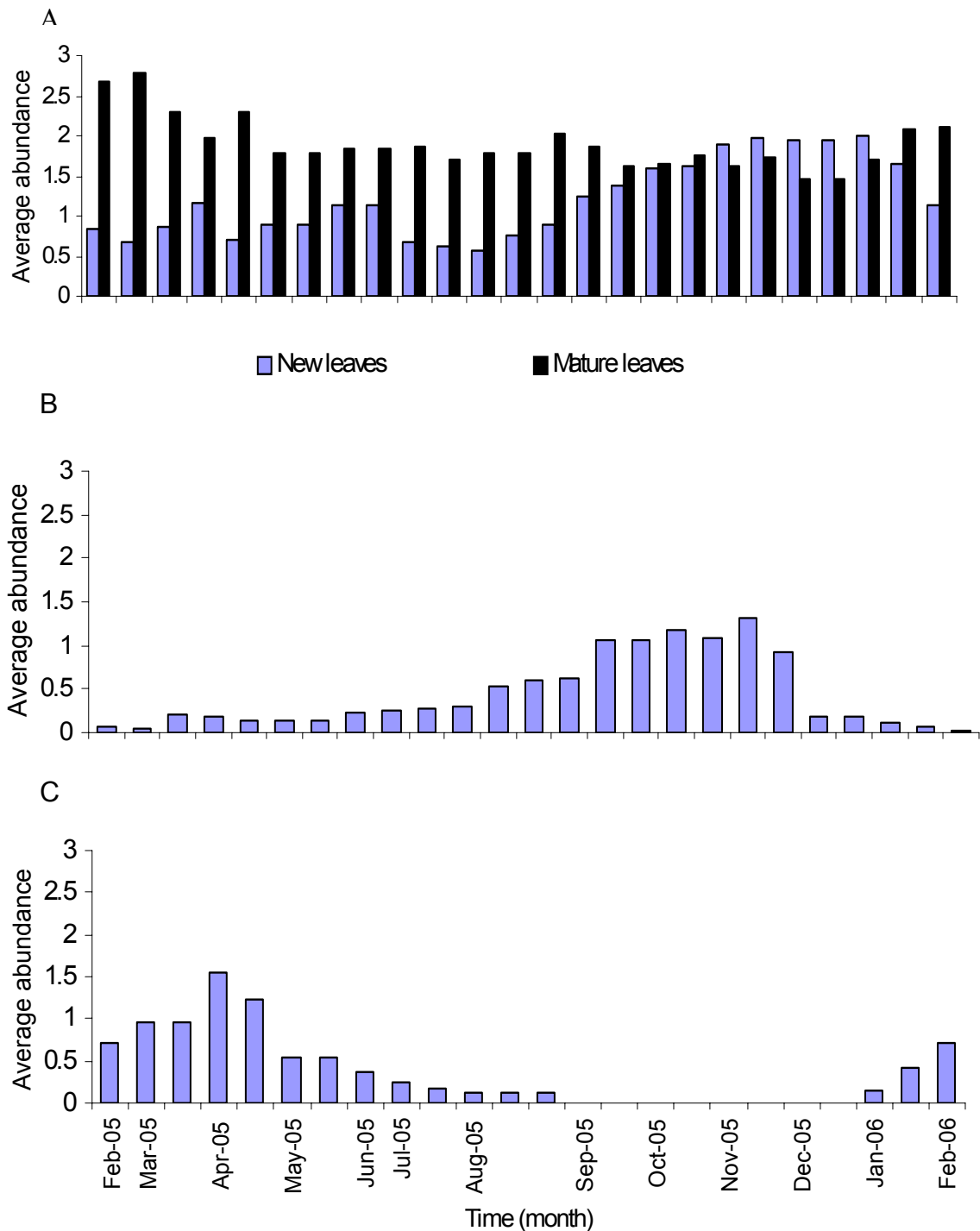


Figure 4.1. Average abundance score of foliage (A), flowers (B) and ripe fruit (C) for all monitored species over a 13-month period.

Mature and new foliage were available throughout the year (Fig 4.1A). Mature foliage remained abundant with minor fluctuations occurring throughout the year. Availability was

slightly higher over the summer months. New foliage was scarce during autumn and winter but increased from mid-August to a peak period between October and January.

Flowers were available throughout the year with a peak period occurring between September and October (Fig 4.1B). Few flowers were present on monitored species between January and early March until flowering increased during August.

The abundance of ripe fruit on monitored individuals was fairly low throughout the year (Fig 4.1C). No ripe fruit were available on monitored individuals between September and December. The amount of ripe fruit increased over summer with a peak period occurring in March and April.

4.3.2 Phenology of individual species

4.3.2.1 Fruit

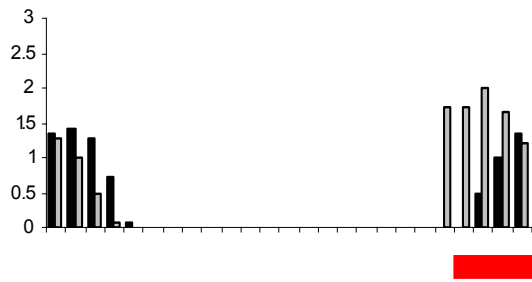
Fuchsia and wineberry had the most contracted fruiting seasons (Fig. 4.2A and B). For fuchsia the transition from full-sized green fruit to ripe fruit was quite rapid with ripe fruit appearing a month after the first unripe fruit was observed. Fruiting was fairly synchronous for both species with ripe fruit appearing on almost all trees simultaneously. A few monitored and unmonitored individuals were observed producing relatively large crops of ripe fruit but most individuals were producing scarce to moderate amounts of fruit.

Kaikomako and ngaio had similar fruiting patterns (Fig. 4.2C and D). Both these species held fruit at varying stages of ripeness. Kaikomako trees produced small quantities of ripe fruit throughout the fruiting period with abundance peaking in March then rapidly declining. In contrast to kaikomako, ngaio produced large amounts of ripe fruit during peak fruiting.

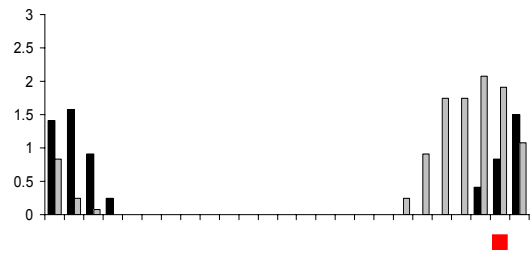
Horopito, poroporo and mahoe (Fig. 4.2E, F and G) showed extended fruiting periods due to multiple cohorts of fruit produced over the period. Poroporo had the longest fruiting season of all monitored species. The abundance of ripe fruit decreased rapidly on horopito and poroporo despite unripe fruit remaining on plants. Unlike the other monitored species, fruiting of mahoe showed some degree of asynchrony with trees staggering their fruiting slightly.

Pate was the last species to fruit in the 2005 season; monitored individuals produced very small amounts of ripe fruit (Fig. 4.2H).

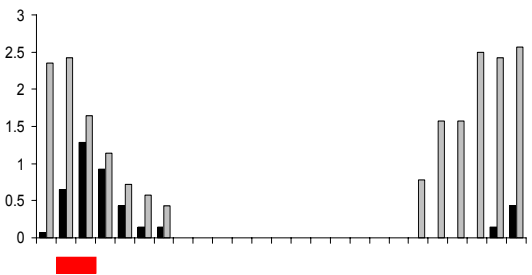
A Fuchsia



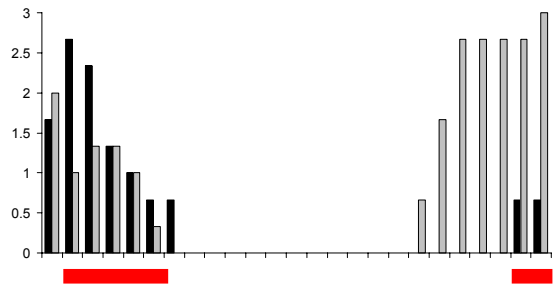
B Wineberry



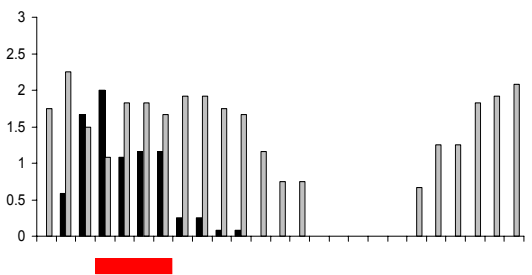
C Kaikomako



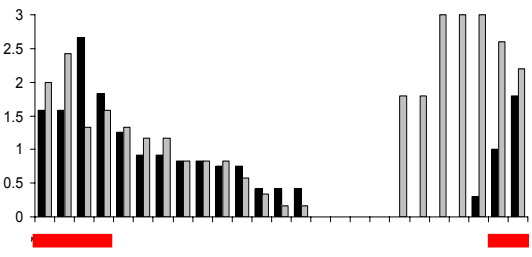
D Ngaio



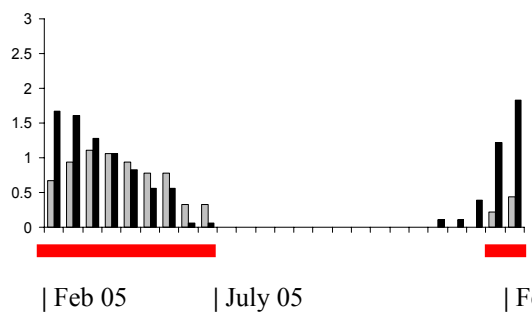
E Horopito



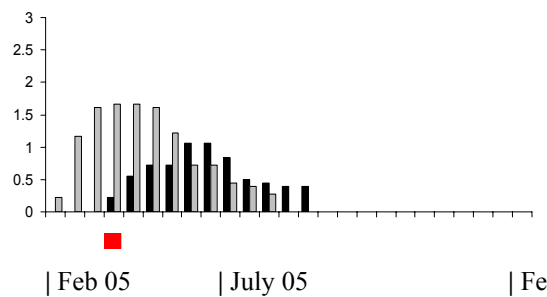
F Poroporo



G Mahoe



H Pate



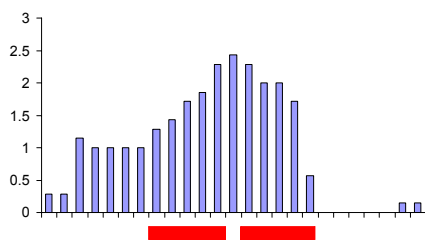
period eaten by kereru
 ripe fruit
 unripe fruit

Figure 4.2. Average abundance of ripe and unripe fruit for each monitored species over a 13-month period.

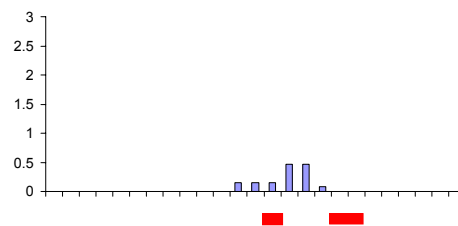
4.3.2.2. Flowers

Tree lucerne, kowhai and broom all had a single flowering episode (Fig 4.3A, B and C). In contrast broom flowered three times during the year, although the first two flowering episodes were negligible (Fig 4.3D). Fuchsia and tree lucerne both showed extended flowering periods (Fig 4.3). Tree lucerne had the earliest peak flowering in late winter; peak flowering for kowhai, fuchsia and broom occurred in spring. The first kowhai flowers appeared as early as July on un-monitored individuals although they were not observed on monitored trees until August. On average monitored individuals showed very low abundance of flowers throughout the flowering period. Most monitored kowhai trees flowered plentifully but because flowering of kowhai is staggered, few monitored individuals were flowering at the same time causing average values for each week to be small.

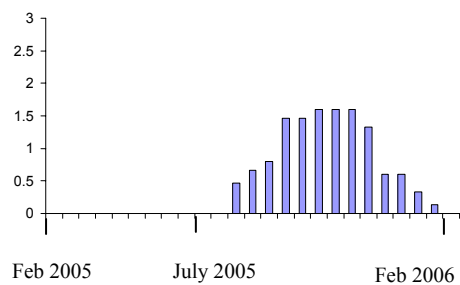
A Tree lucerne



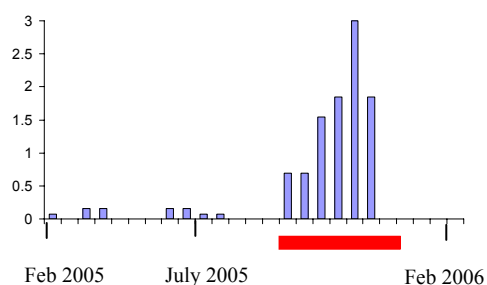
B Kowhai



C Fuchsia



D Broom



■ period eaten by kereru

Figure 4.3. Average abundance of flowers on monitored species over a 13-month period.

4.3.2.3 Foliage

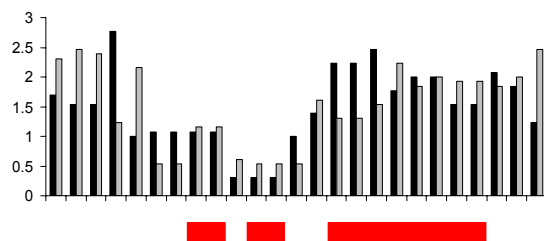
Mature and new foliage was available throughout the year on broom and tree lucerne (Fig 4.4A and B). Growth of new foliage was staggered among individuals of broom so newly budded leaves were available for the entire period of new growth. All individuals of tree lucerne

produced leaf buds throughout the year although newly-budded leaves were more common during spring and early summer.

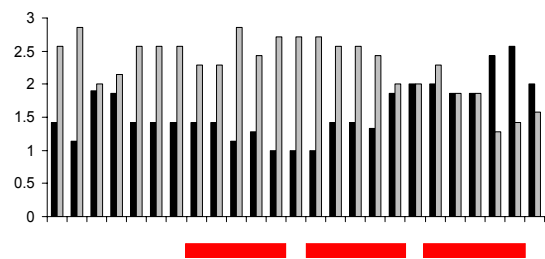
Mahoe showed a fairly constant level of mature foliage throughout the year (Fig 4.4C). Slight dips in the abundance of mature leaves corresponded with two flushes of new leaves.

Kowhai was the only species that did not retain mature foliage throughout the year (Fig 4.4D). Many individuals lost almost all of their old leaves over winter while others retained depleted numbers. A flush of newly-budded leaves paralleled with mature foliage becoming absent.

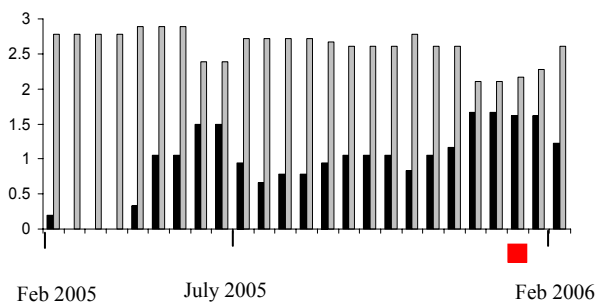
A Broom



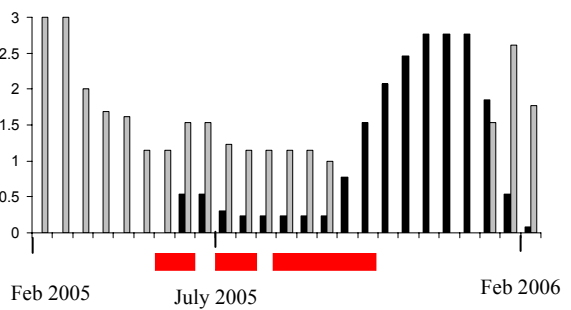
B Tree lucerne



C Mahoe



D Kowhai



■ period eaten by kereru ■ new leaves ■ old leaves

Figure 4.4. Average abundance of mature and immature foliage on monitored species over a 13-month period.

4.4 Discussion

All monitored species showed highly seasonal patterns of fruiting typical of temperate forests. Ripe fruit of one species or another was available for eight months of the year but was scarce over winter and early summer and could not be relied on as a sole food source. Times of peak fruiting in Hinewai were similar to sites in Auckland (Dijkgraaf, 2002) and Whirinaki Forest

Park (Hill, 2003) except that in the Auckland study some fruit was available throughout the year and in Whirinaki no species had peak fruiting during winter. A study of kereru diet at Maungatapere, Northland also found that fruit was available year round (Pierce and Graham, 1995).

Increasing latitude and variation in the age, structure and species composition of the canopies could explain some differences in fruit production between sites. For example, Clout *et al.* (1995) suggested that Mohi Bush, Hawkes Bay, had relatively low species diversity and contracted fruiting seasons due to the removal of podocarps by logging. Study areas in Wenderholm (Dijkgraaf, 2002) and Whirinaki Forest Park (Hill 2003) were mostly old growth forest with emergent species, and reasonably open canopies above the sub-canopy. Most areas of Hinewai Reserve lacked old growth forest and the main canopy was comprised of a limited number of sub-canopy species of roughly similar age. Unlike emergent species these individuals compete for available light and many are not yet in the prime of fruit production. A combination of these factors could have resulted in a reduced production of fruit and a shorter fruiting season. However, phenology studies at these sites were done in different years, a factor that also needs to be taken into account as the timing of fruiting and changes in fruit abundance from year to year (i.e. influenced by climate or species that mast fruit) (Dijkgraaf, 2002).

Three groups of fruiting species were identified in Hinewai Reserve using phenology data. For the early fruiting species, peak production of ripe fruit occurred in late summer. The second fruiting group were the autumn fruiting species whose peak fruiting period occurred over March and April. These species produced several cohorts of fruit resulting in ripe fruit being available into winter. Extended fruiting of autumn fruiters was also observed by Hill (2003) but not by Dijkgraaf (2002). Dijkgraaf (2002) suggested that extended fruiting seasons become more common as latitude increases. The final fruiting group identified was the winter fruiting group. Pate was the only monitored species that fell into this category.

Timing of fruiting and the abundance of fruit on monitored species appeared to be representative of most species that were observed fruiting in Hinewai during the study period (pers. obs.). Unmonitored species that were observed producing ripe fruit during these periods were: five-finger (summer); kawakawa (*Macropiper excelsum*) (late summer/autumn), cabbage tree (*Cordyline australis*) and supplejack (*Rhipogonum scandens*) (autumn); rohutu (winter). Karamu (*Coprosma robusta*) was observed to have a slightly different pattern from other

autumn fruiterers in that peak fruiting lasted for several months due to asynchronous fruiting on and between individuals. Pigeonwood was the only other species observed to exhibit pronounced asynchrony of fruiting between individuals. Pigeonwood had the longest fruiting season compared with any monitored or unmonitored species; ripe fruit was available from early summer through to the end of winter.

Individuals of all species in full sun (monitored and un-monitored) appeared to produce heavier crops of fruit than those in the shade (*pers. obs.*). Hill (2003) and Dijkgraaf (2002) also noted increased fruit production in areas most exposed to sunlight. Because of the fragmented nature of forest in Hinewai Reserve, marginal areas were common and were possibly important habitat for species with a partly frugivorous diet, such as kereru, who benefit from high levels of fruit production.

Timing of new leaf growth varied between individuals of the same species and between species creating a continuous source of fresh leaves for kereru to eat. New leaves were available throughout the year on broom and tree lucerne but not on the native species monitored. Broom was the only common introduced species with leaves eaten by kereru on the reserve and therefore the only reliable source of new leaves at times when new growth was scarce on native species. Unsurprisingly, flowering peaked in spring just before unripe fruit started to appear. Broom and tree lucerne produced flowers in immense numbers during their peak flowering period and attracted a range of birds and insects. Tree lucerne was particularly well used considering the limited number available.

Both 2004 and 2005 were abnormal years for climatic conditions. It is assumed that climatic conditions altered phenology patterns in both these years, although there is no data to show this. Late winter blizzards and very cool temperatures were characteristic of the 2004 year for the lower South Island (NIWA, 2005). This caused delayed ripening of fruit in Hinewai Reserve (Hugh Wilson, *pers. comm.*) and possibly also delayed peak fruiting. It may also have altered patterns of leaf and flower growth in Otanerito Valley. In comparison 2005 was an exceptionally warm and dry year in the South Island (NIWA, 2006). Winter and spring were mild in Otanerito Valley causing early growth of new shoots and flowers (Brian Narbey, *pers. comm.*). It may also have induced the fruiting season to start earlier than normal. Timing of phenology events is likely to change slightly each year and this is something kereru would have to account for in their feeding behaviour.

It is probable that the abundance of ripe fruit, and length of fruiting season was influenced by the removal of fruit by browsing birds, possums and invertebrates. Poroporo was taken by both kereru who ate it whole and smaller native and introduced birds who pecked at the fruit. There is a high density of possums in Hinewai Reserve (Hugh Wilson, *pers. comm.*) and it can be assumed that they would impact on fruit abundance. Small-fruited species such as pate, wineberry and kaikomako were particularly attractive to small birds but not much fruit appeared to be removed by kereru in areas frequented by tagged kereru (see Chapter 6). Both kereru and smaller birds used mahoe, ngaio and horopito heavily. Removal of fruit by large flocks of kereru is likely to have caused the sharp decline in fruit abundance early in the fruiting season for horopito, poroporo and ngaio.

Browsing of mahoe leaves by kereru was not common so was not a likely influence on phenology of this species; only one monitored individual was browsed by possums. In some areas large flocks of kereru fed on leaves and flowers of broom, but because this species was so abundant and widely distributed browsing was unlikely to have influenced phenology results. Kereru fed heavily on mature kowhai leaves over winter and this would have contributed to loss of leaves over that period. The kowhai moth caterpillar (*Uresiphita polygonalis maoralis*) is also known to browse heavily on leaves of kowhai. Heavy browsing of tree lucerne by kereru may have induced the large flush of new growth in early summer as trees were almost stripped bare of leaves. Chapter 5 will illustrate foods eaten by kereru throughout the study period and how diet related to the phenological patterns described in this chapter.

Chapter 5

Feeding

5.1 Introduction

Studies of kereru diet at locations throughout New Zealand have shown that diet is site specific (Bell, 1996; Clout *et al.* 1986; Clout *et al.* 1991; Dunn, 1981; Hill, 2003; Pierce & Graham, 1995; Ridley, 1998; Schotborgh, 2005). Kereru in the urban-rural landscape face a whole new dietary challenge due to significant modifications to the landscape they had co-evolved with. This new landscape is a mosaic of residential properties, farmland and small native forest fragments, generally with very little old growth forest.

In the urban-rural habitat on Banks Peninsula foliage and flowers of introduced legumes, kowhai and deciduous trees comprise the largest proportion of winter and spring diet (J. Lyall, *pers. comm.*; Schotborgh, 2005). Use of foliage generally is considered to be a ‘starvation diet’ for kereru that is resorted to only when fruit is unavailable (Hill, 2003). However Schotborgh (2005) found that kereru bred successfully even when their diet consisted almost entirely of leaves of introduced legumes and deciduous species prior to the breeding season.

Schotborgh (2005) studied diet of kereru in two highly modified areas in the Lyttelton Harbour basin on Banks Peninsula. The habitat at these study sites was considerably fragmented, consisting mostly of introduced plant species with small native forest fragments few and far between. In contrast, the Hinewai Reserve study site contains relatively large contiguous areas of native vegetation along with a few introduced species. It was expected that quality and quantity of food in the Hinewai Reserve study site would be higher than in the Lyttelton Harbour area and that kereru there would make use of the higher proportion of native species available (K-J. Wilson, *pers. comm.*).

This feeding study complements Schotborgh (2005). In this chapter the following questions will be addressed and comparisons made with Schotborgh (2005) and Hill (2003):

1. What plant species and food types are kereru eating and what proportion of the diet does each comprise?
2. What is the relative importance of each food species throughout the year?

3. At what time of the year is each species eaten and is this reflected by phenology patterns?
4. What are the management implications of these findings for kereru on Banks Peninsula?

5.2 Methodology

Feeding observations were made while kereru were radio tracked for home range data from February 2005 to February 2006. Radio tracking methodology is discussed in Chapter 3.

Each time a tagged kereru was sighted it was observed continuously for 15-30 minutes and all feeding activity recorded (see section 3.3.1 for more detail). The first species consumed and all plant parts (food types) eaten for that species were recorded during each observation period. Food type was separated into the following categories: ripe fruit, unripe fruit, flowers and leaves (mature and immature). Fruit was classified as ripe if it was close to the colour recorded in Poole and Adams (1994). Any other colours were classified as unripe. The times of the year when predominately new shoots were being consumed were noted by the observer but new and old growth foliage was not distinguished in the analysis.

Data from the following areas were pooled together for analysis: Hinewai Reserve (including lower Otanerito Valley and Sleepy Bay gully) and Akaroa. The number of tagged kereru resident at these sites was 12 (before two deaths in July) and three respectively. There were some differences in the use of species by kereru at higher altitude (near Purple Peak Saddle) that were not highlighted by analysis of the Hinewai Reserve study site in its entirety. An analysis of the relative importance of food species was done for all kereru in the Hinewai Reserve study site, and another just for kereru near Purple Peak Saddle.

5.2.1 Food species eaten

A record was kept of species eaten during each field week (period of five consecutive days every second week). A score of '1' was given when at least one kereru was recorded eating a particular species in each field week. Food types eaten in each field week were also recorded for each species. These data were used to create a table illustrating food species and food types eaten over time and also a bar chart of the proportion of native vs. introduced species eaten over time.

5.2.2 Relative importance of food species

Statistical analysis of data sets was not viable due to inconsistency in the number of kereru observed feeding and the number of feeding observations for each kereru each week. There was also a lack of data on the relative availability of plant species in the study areas. These factors meant it was not possible to reliably assess whether kereru preferred certain plant species or food types (i.e. a comparison of species composition or selection indices). It was decided to use the same method as Schotborgh (2005) to show the importance of each species *relative* to all other species eaten during each field week.

Two calculations were used as a measure of how frequently each species was eaten each field week:

- 1) The proportion of kereru observed eating each food species and
- 2) the proportion of feeding observations recorded on each food species.

Food species are referred to as ‘frequently eaten’ if the proportion value is ≥ 0.4 in either calculation or ‘very frequently eaten’ if the value is ≥ 0.4 in both calculations (Schotborgh, 2005).

After looking at the raw data 0.4 was arbitrarily chosen because values ≥ 0.4 reflected the weeks where only one or two species were being heavily used and therefore were important compared to other species eaten in the same week. Raw data is shown in Appendix 3. In field weeks when feeding was spread over a number of species, no species reached the threshold. This method was thought to accurately reflect biological events. A summary figure was created to illustrate relative importance of species and what times of the year the threshold was reached.

5.2.3 Other feeding observations in Akaroa

Observations of kereru feeding were recorded by Dr. John McIlroy in Akaroa between April 2003 and February 2006. When the raw data collected by Dr. McIlroy were evaluated it was clear that data collected from the three tagged kereru were not representative of all kereru in Akaroa. Dr. McIlroy kindly allowed his data be included in this chapter to supplement data gathered from tagged kereru in Akaroa to present more characteristic results. Dr. McIlroy lived on Hempleman Drive, Glen Bay, on the southern side of Akaroa Township. He recorded all personal observations of kereru feeding around his home during the day and on regular late-afternoon walks in his immediate neighbourhood and the Garden of Tane (roughly a 1 km radius around his home). He also recorded feeding observations made in central Akaroa

Township, but only if kereru had not been observed eating that species in his neighbourhood during the same month. Data was pooled for each month. Plant species and food types eaten were recorded. Separate analysis was done for Dr. McIlroy's data because feeding observations of untagged kereru were used; however the results are described and discussed in this chapter.

5.2.4 Feeding in relation to phenology

This was only done for the Hinewai Reserve study site, as phenology monitoring was not carried out in Akaroa. A summary table is presented to put feeding results into context using phenology data (see Chapter 4).

5.3 Results

5.3.1 Species and food types eaten

5.3.1.1 Hinewai Reserve study site

A total of 26 species were eaten throughout the study period (Fig 5.1). Six of these species were introduced and 20 were native. Kereru were observed eating between two and eight species each week (Fig 5.1). The number of species eaten each week fluctuated during the year with no apparent trend. Three or less species were recorded in February, late-may, mid to late-August, early-November and early-December.

5.3.1.2 Akaroa study site

A total of 21 species were eaten at the Akaroa study site throughout the study period (Fig 5.1). Twelve of these were introduced and nine were native. Kereru in Akaroa were observed eating between one and four species each week (Fig 5.1). Diversity of species eaten was highest during late summer, autumn and early winter when four species were eaten most weeks and again during the last week in September. Between mid-July and the end of August only tree lucerne was observed being eaten.

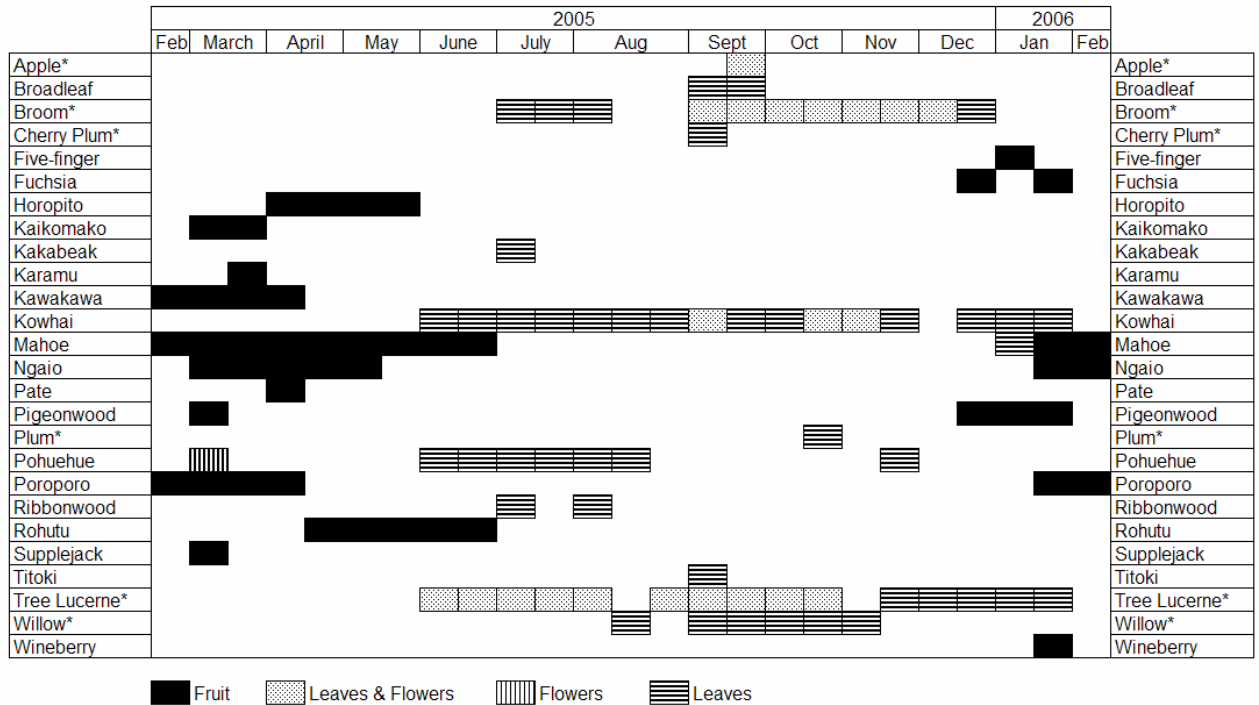
5.3.2 Relative importance of kereru food species

5.3.2.1 Hinewai Reserve study site

Six species were classed as being 'very frequently eaten' during some field weeks, these were: broom, kowhai, mahoe, poroporo, rohutu and tree lucerne (Fig 5.2). Broom and tree lucerne are introduced. Broom, kowhai, mahoe and poroporo were also classed as 'frequently eaten' in

some field weeks. Kawakawa, ngaio and pigeonwood were also classed as being ‘frequently eaten’ during some field weeks (Fig 5.2).

Hinewai Reserve



Akaroa

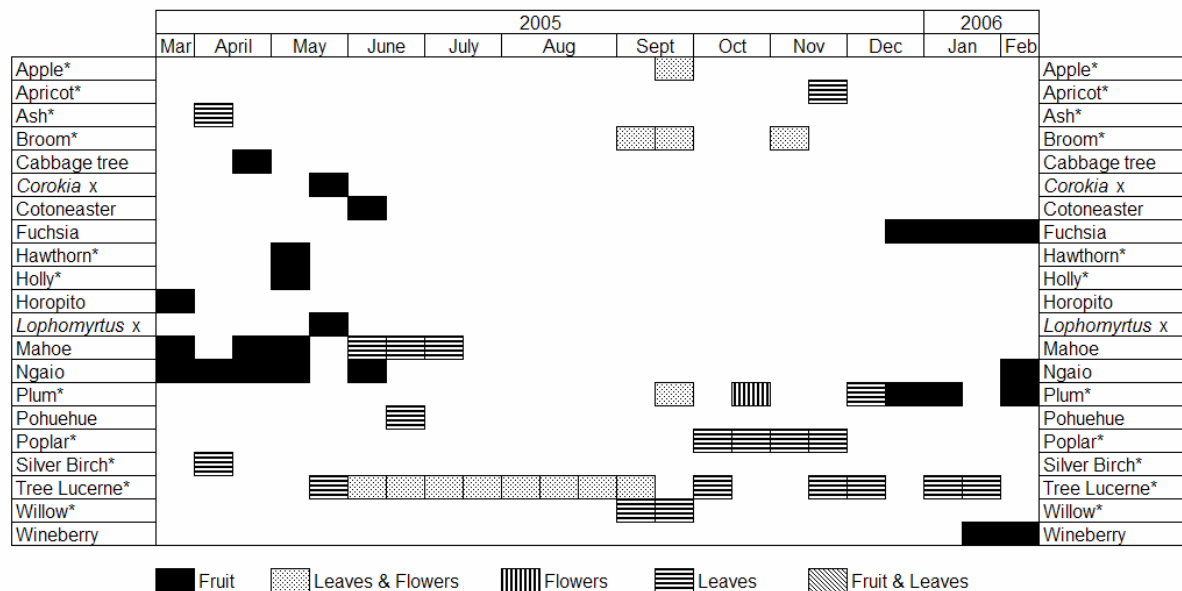
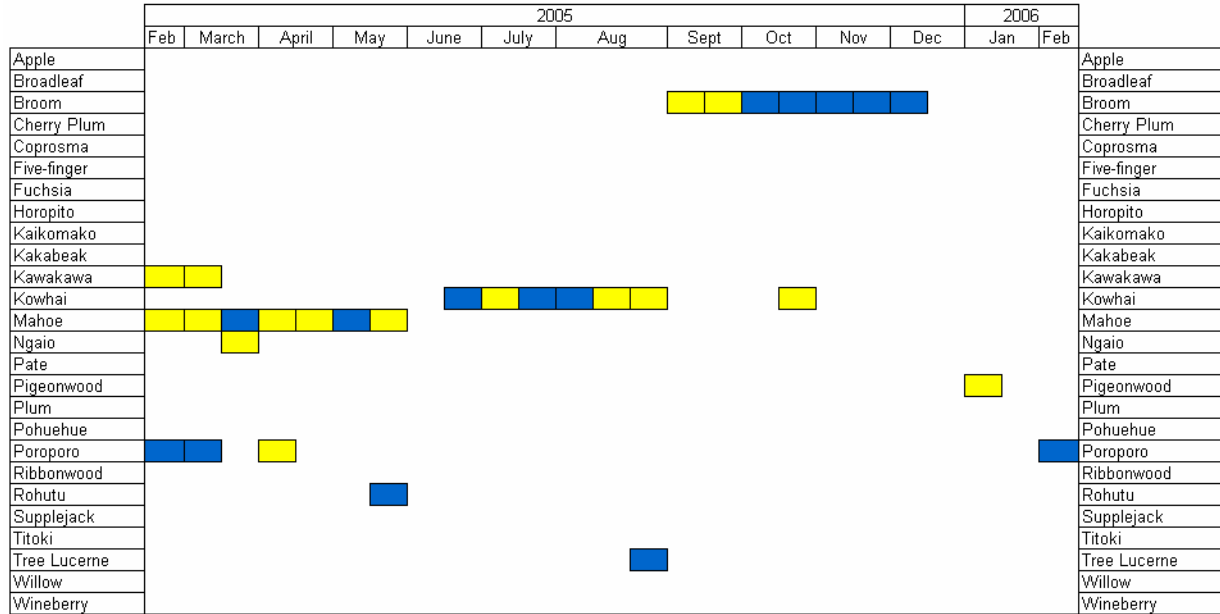
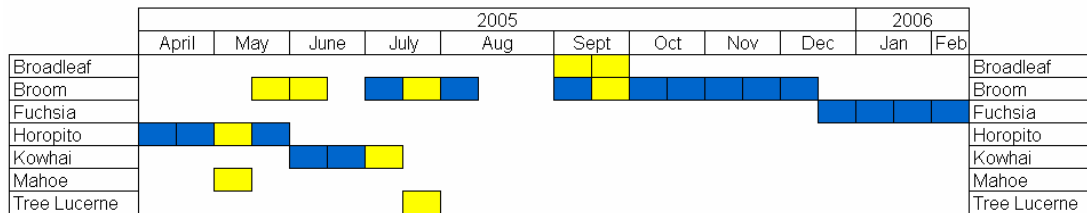


Figure 5.1. Food species and food types eaten over time in two areas: Hinewai Reserve and Akaroa. Introduced species are marked with a (*).

Hinewai Reserve



Purple Peak Saddle



Akaroa

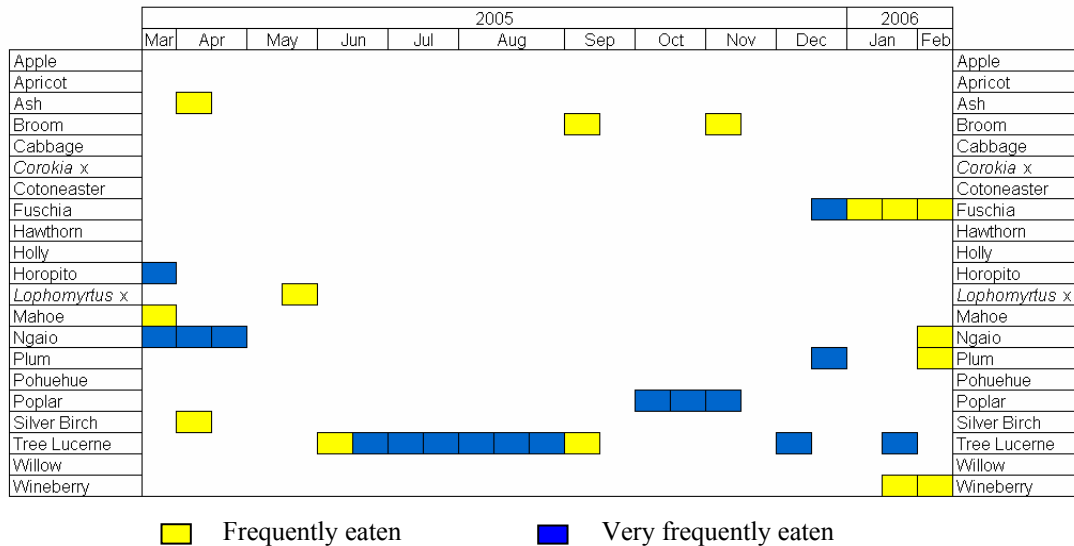


Figure 5.2. The relative importance of species over time at three sites: Hinewai Reserve, Purple Peak Saddle and Akaroa. No feeding observations were made on kereru at Purple Peak Saddle during two weeks in August. All plant species were eaten, but only those that met the proportion thresholds are coloured.

Figure 5.2 also shows that during early-June, late-December, and late-January no species were classed as either ‘frequently eaten’ or ‘very frequently eaten’. This indicates similar use of many species.

5.3.2.2 Purple Peak Saddle

All species eaten at Purple Peak Saddle were classed as ‘very frequently eaten’ or ‘frequently eaten’ throughout the year (Fig 5.2). Two of these species, broom and tree lucerne, were introduced.

5.3.2.3 Akaroa study site

Fuchsia, horopito, ngaio, plum, poplar and tree lucerne were classed as ‘very frequently eaten’ during some field weeks (Fig 5.2). Plum, poplar and tree lucerne are introduced. Ash, broom, *Lophomyrtus x*, mahoe, silver birch and wineberry were classed as ‘frequently eaten’ during some field weeks. Figure 5.2 also shows that:

- In March and late-December two species were ‘very frequently eaten’ (horopito and ngaio in March; fuchsia and plum in late-December).
- In early-May, late-September and late-November no species were classified as either ‘frequently eaten’ or ‘very frequently eaten’ indicating similar use of many species.

5.3.3 Proportion of food types eaten

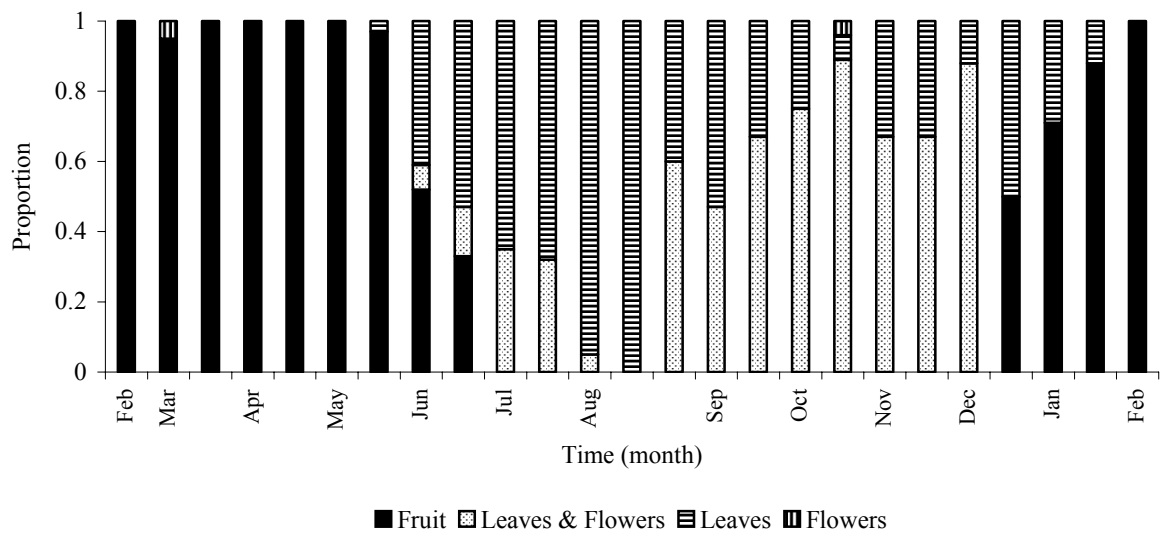
5.3.3.1 Hinewai Reserve study site

The diet of kereru in late summer and autumn consisted almost entirely of fruit (Fig 5.3). Fruit continued to be eaten in June but increasing amounts of leaves and flowers made up the diet. Feeding on fruit ceased in July with a switch to leaves and flowers of several native and introduced species. The proportion of flowers in the diet increased during spring and early summer. In late-December half of feeding observations were of fruit and consumption of fruit increased as summer progressed.

5.3.3.2 Akaroa study site

Feeding observations between late-December and March consisted almost entirely of fruit (Fig 5.3). Fruit of several introduced and native autumn fruiting species were eaten between April and late-June. In July kereru switched to foliage and flowers. Mostly leaves and flowers were eaten during winter and early spring. In late spring and early-December a large part of the diet was made up of the new leaves of deciduous trees.

Hinewai Reserve



Akaroa

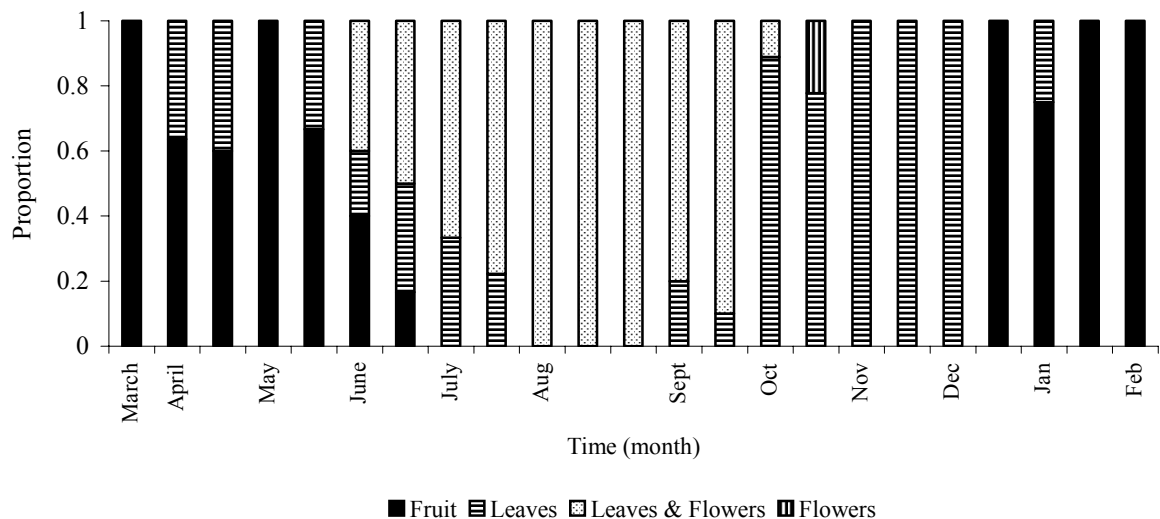


Figure 5.3. The proportion of each food type consumed over time in two areas: Hinewai Reserve and Akaroa.

5.3.4 Proportion of native vs. introduced species eaten

5.3.4.1 Hinewai Reserve study site

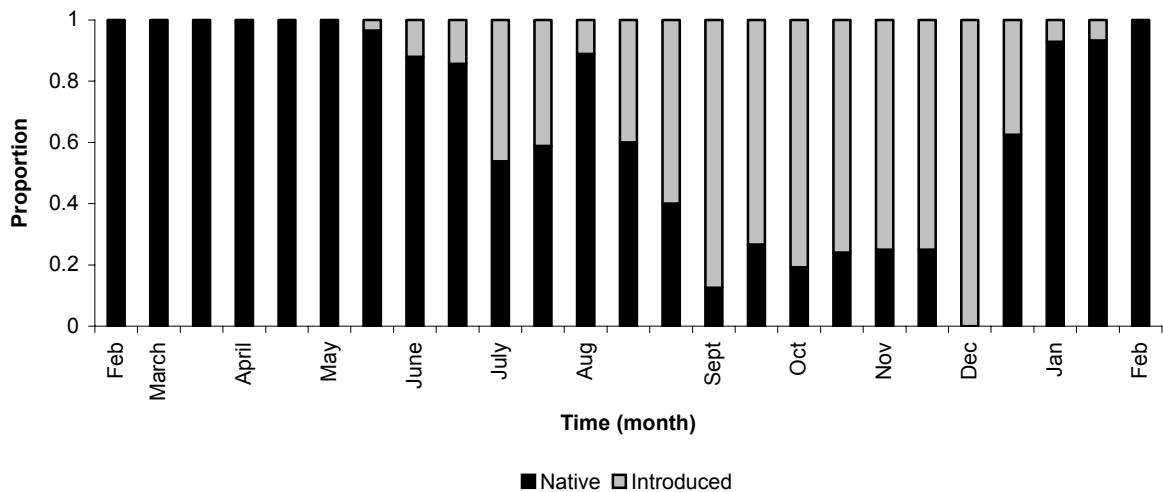
Between February and end of May only native species were eaten (Fig 5.4). In early winter small amounts of foliage of introduced species began creeping into the diet and this increased as winter progressed. During spring kereru were feeding almost entirely on introduced species.

Feeding on native fruit resumed again in December and by January over 90% of the diet comprised of native fruit.

5.3.4.2 Akaroa study site

Early-March and early-April were the only times of the year that kereru ate only native species (Fig 5.4). Use of native species was highest during summer and autumn. In early winter and early summer roughly 50% of the diet was comprised of native species. By mid-winter all of the diet comprised of foliage and flowers of introduced species and this continued throughout spring and early-December.

Hinewai Reserve



Akaroa

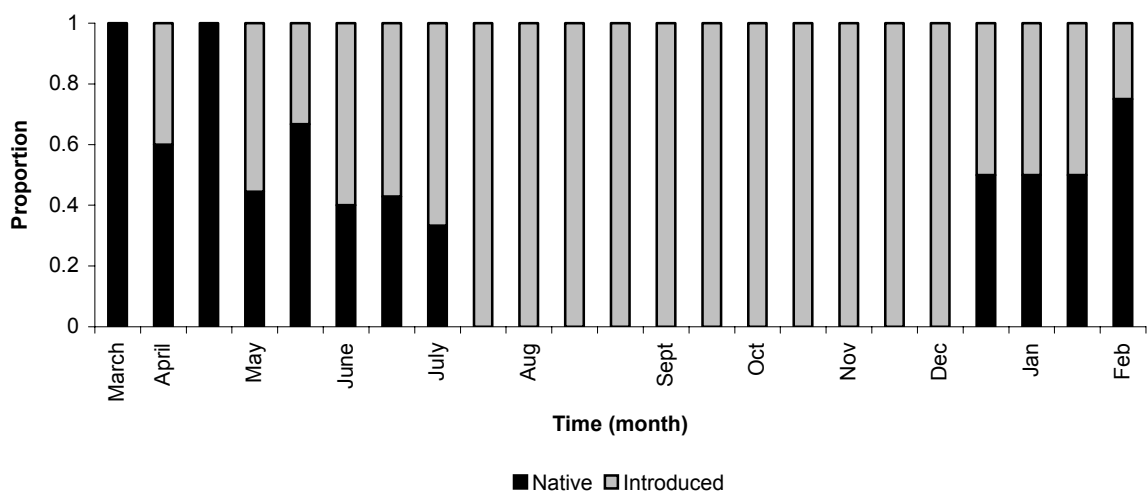


Figure 5.4. The proportion of native and introduced species eaten over time in two areas: Hinewai Reserve and Akaroa.

5.3.5 Other feeding results from Akaroa

5.3.5.1 Species Eaten

Kereru were observed eating a total of 21 species throughout the 34-month period (Fig 5.5). Fifteen of these were introduced and six were native. Between one and six species were eaten each month. No trend is apparent between time of the year and the number of species eaten, but the number of species eaten over winter is slightly lower on average than in other times of the year.

5.3.5.2 Proportion of food parts eaten

A high proportion of fruit was eaten from mid-summer to early autumn in all years (Fig 5.6). However very little fruit was eaten in early winter in this area. Foliage and flowers made up the entire diet during winter, spring and early summer.

5.3.5.3 Proportion of native vs. introduced species eaten

A higher percentage of native species were eaten during summer and autumn in 2004 and 2005, relative to other months of the year (Fig 5.7). In 2003 the months with the highest percentage of native species were April and July. January and February 2006 also had relatively high percentages of native species eaten compared with other months in previous years. During all other months of the year very few or no native species were eaten by kereru.

5.3.5.4 Comparison with results from radio-tagged kereru in Akaroa

Cherry, crab apple, kohuhu, laburnum, lacebark, phoenix palm, virgilia and yew were all species that tagged kereru in Akaroa were not observed eating (Fig. 5.3 & 5.5). Dr. McIlroy's data showed that un-tagged kereru ate a similar pattern of food types to tagged kereru, but ate more fruit during autumn and less fruit in summer and winter (Fig. 5.4 & 5.6). Un-tagged kereru ate less native species throughout the year (Fig. 5.5 & 5.7).

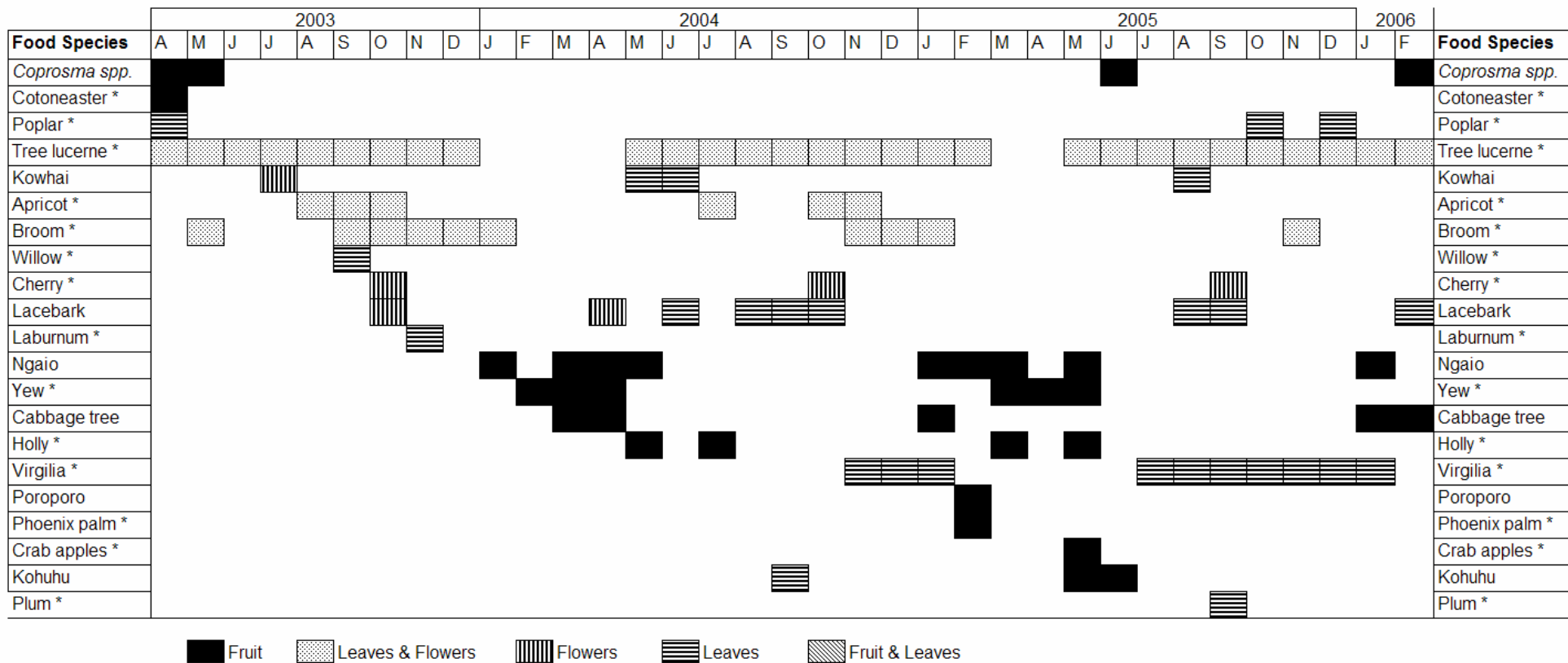


Figure 5.5. Plant species and food parts eaten by untagged kereru between April 2003 and February 2006 in Akaroa. Introduced species are shown with a (*).

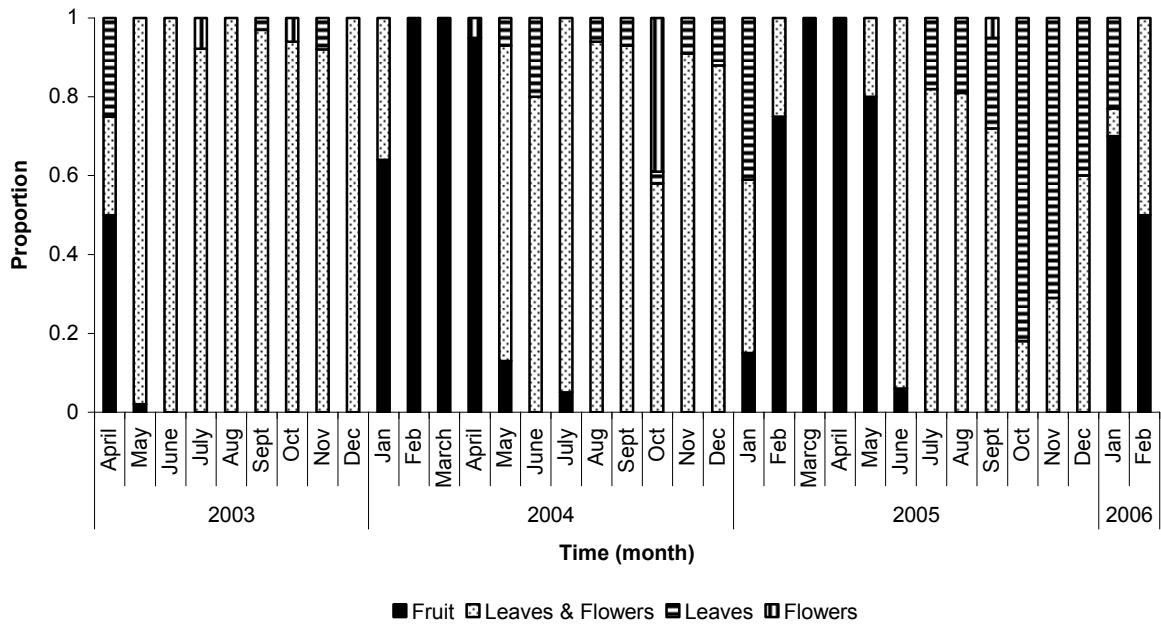


Figure 5.6. The proportion of food parts eaten by untagged kereru in Akaroa between April 2003 and February 2006.

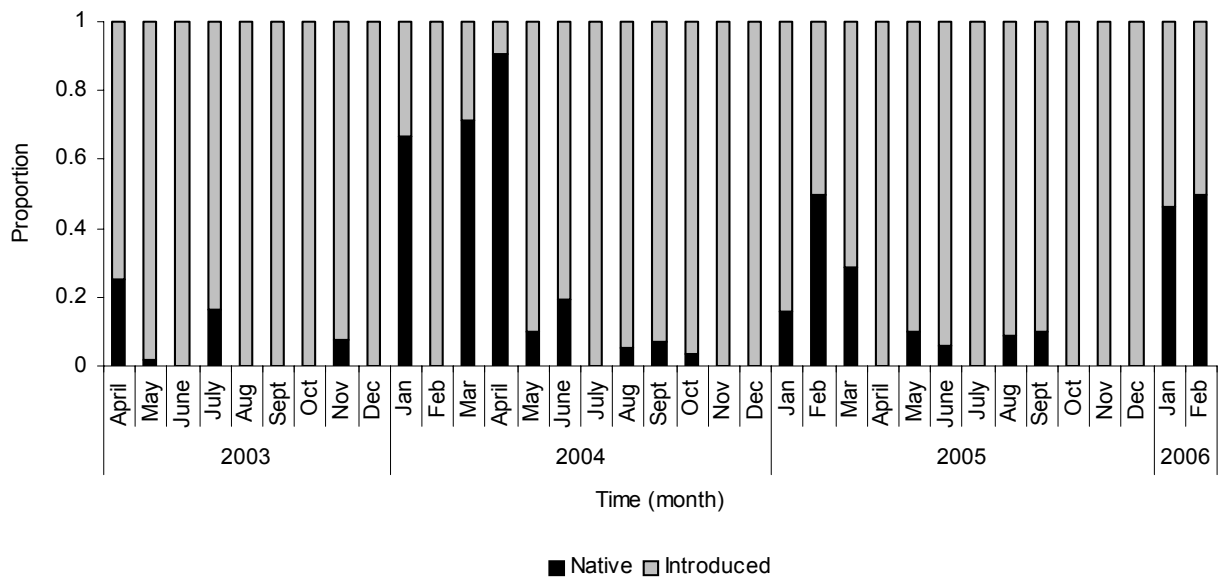


Figure 5.7. The proportion of native vs. introduced species eaten by untagged kereru in Akaroa between April 2003 and February 2006.

5.3.6 Feeding in association with phenology

Chapter 4 (4.3.2) illustrates the availability and abundance of ripe fruit; flowers and foliage for plant species selected for phenology monitoring in Hinewai Reserve. These figures also show times of the year that these species and food types were eaten by kereru. Table 5.1 is a summary of these results.

Table 5.1. Summary of feeding periods in relation to availability of monitored species.

Ripe Fruit	Months eaten	Months available on monitored trees	Eaten during peak period?
fuchsia	December-February	January-February	Yes
horopito	April-May	March-July	Yes
kaikomako	March	January-May	Yes
mahoe	January-June	January-June	Yes
ngaio	January-May	January-May	Yes
pate	April	April-August	No
poroporo	January-April	January-August	Yes
wineberry	January	January-April	No
Flowers	Months eaten	Months available on monitored trees	
broom	September-December	September-November	Yes
fuchsia	-	August-January	-
kowhai	August & October-November	August-October	No
tree lucerne	June-October	January-October	Yes
Foliage	Months eaten	Months available on monitored trees	
broom	June-August September-December	February-February	Yes
kowhai	April-August	April-February	No
mahoe	January	April-February	Yes
tree lucerne	June-January	February-February	Yes

N.B. for 'Foliage' applies to new leaves only - No tagged kereru were recorded eating this food type

Months are inclusive, 'Peak period' refers to time of peak production for each food type

5.4 Discussion

5.4.1 Key findings regarding food species

Year-round availability of quality food sources, and the fact that no regular or long-term feeding visits were made out of Otanerito valley by tagged kereru, indicates that a plentiful and continuous supply of food is available at that site. Movement of Akaroa resident kereru to feed on Horopito at Purple Peak Saddle may indicate a shortage of native fruit in autumn.

Availability of native species at each site was reflected by the total proportion of native and introduced food species used by kereru. There is a clear trend from minimal use of introduced species in Whirinaki Forest Park to greatest use in the highly modified urban sites such as Akaroa. At the Hinewai study site 76% of food species used throughout the year were natives compared with 46% in Lyttelton Harbour, 32% in Akaroa (including Glen Bay data) and 95% in Whirinaki Forest (Hill, 2003; Schotborgh, 2005). In this study, on average kereru in Otanerito valley ate the highest proportion of native species throughout the year and Akaroa kereru ate the lowest. It is possible that consumption of native fruit by introduced birds (ie. blackbirds) and bellbirds (*Anthornis melanura*) may have reduced the number of native species eaten in Akaroa in autumn and winter (Dr. J. McIlroy, *pers. comm.*).

The immediate switch to fruit as soon as it became available at both study sites indicated that this was the preferred food type, although when fruit was scarce at the beginning and end of the fruiting season the diet was supplemented with foliage. Native fruit appeared to be preferred in Akaroa as native species were relatively more important in the diet of tagged kereru while fruit trees were producing fruit. Plum trees were used heavily at the start of summer while native fruit was scarce (*pers. obs.*). Pierce and Graham (1995) also found that introduced fruits such as privet were only used when native fruit was scarce at their urban-rural site in Maungatapere, Northland. The Hinewai Reserve study site contained virtually no introduced fruit so preference could not be inferred.

Data collected on un-tagged kereru in Akaroa, suggested usage of a wider range of species than indicated by the three radio-tagged birds. This was not surprising, as the sample size of tagged kereru in Akaroa was very small. The comparison of results also suggested that untagged kereru used different proportions of food types and native species to tagged kereru. This may be due to local variation in vegetation types. However, results for untagged kereru were likely to be influenced by the areas that were visited by Dr. McIlroy. Areas of residential garden

were interspersed by small native forest fragments in areas frequented by tagged kereru; these fragments were used regularly by tagged kereru during some parts of the year. The only native forest fragment frequented by Dr. McIlroy was the Garden of Tane (Dr. J. McIlroy, *pers. comm.*), which contained large numbers of introduced tree species around the margins where kereru were most likely to be seen. Kereru can be very difficult to see in dense canopies and un-tagged birds would have been hard to spot, even for a dedicated observer. These factors may have resulted in more observations being made in gardens (and therefore on introduced species) than in forest fragments.

Although a threshold of ≥ 0.4 was subjectively allocated to denote species with higher use, this number was not completely arbitrary in that careful consideration was given to whether the results accurately reflected biological events (observations of kereru feeding in the field) each month. In weeks where no species reached either threshold, feeding was spread fairly evenly over a few species or sparsely over many species. In some weeks more than one species reached the threshold, this tended to reflect heavy use of different species by sub-sets of kereru. Relative importance of the same species varied between the three areas and different species were also more important in some areas than in others.

Schotborgh (2005) found that when higher numbers of food types were available successively or simultaneously on a species, importance of this species to kereru was likely to be high. Apart from broom in Hinewai Reserve and tree lucerne in Akaroa, species that met this criterion were used as much as, or less than, other 'frequently eaten' species in this study. Only broom in Hinewai appeared to be preferred over species such as mahoe and kowhai, which had a single food type available. Despite new growth of kowhai being abundant and readily accessible it was barely eaten in Hinewai while broom was used heavily. Broom was widespread in the reserve, which could account for its extensive use. However, kereru were flying from roosting sites with numerous kowhai trees less than 50 metres away, to patches of broom up to 1 km away. In comparison, new growth of kowhai was an important food source in Whirinaki Forest (Hill, 2003). However without data comparing the nitrogen and protein contents of both species, whether broom is more nutritious remains a moot point.

Leaves of legumes such as kowhai, broom and tree lucerne are rich in nitrogen, a precursor for protein (Webb *et al.*, 1988). Hill (2003) found that new leaves of kowhai and mahoe had more than four times the protein content than fruits that were analysed (mahoe, tawa, miro, fuchsia, wineberry and karamu). Schotborgh (2005) suggested that the protein levels of legumes and

deciduous species eaten by kereru in Lyttelton Harbour triggered breeding or at least enabled kereru to breed on a diet of foliage. Several chicks fledged before ripe fruit was available (Schotborgh, 2005). Broom was the main species eaten prior to the breeding season in this study so it is possible that availability of this species triggered breeding. However both chicks fledged during the fruiting season. It has been suggested that fruit is required to trigger breeding (Clout, 1990; Clout *et al.*, 1995; Mander *et al.*, 1998). The results of this study and Schotborgh (2005) have narrowed down the list of likely chemicals required by breeding kereru. As fruit was not available prior to, and during much of, the breeding season at either of these sites it is not known whether kereru would have preferred fruit over foliage had it been available.

Local variation in feeding ecology between areas within Akaroa and Otanerito Valley indicates that sampling in this study wasn't completely representative. A better understanding of the relative importance of species in all areas could have been made if greater sample sizes and a more even spread of kereru had been used for feeding observation. By capturing six kereru at the top of the reserve and nine at the bottom, it was hoped that a fairly representative sample of the whole reserve would be studied but unintentional capture of four non-resident (including the Sleepy Bay resident) kereru thwarted this plan. Tagged kereru did not use as much of Hinewai Reserve as expected and spent most of their time on the margins of the reserve or in neighbouring forest fragments.

5.4.2 Feeding in relation to phenology data

All species monitored for fruit abundance were eaten by kereru during the study period. Untagged kereru were seen eating fruit of fuchsia on Purple Peak Saddle before tagged birds were caught. It is likely that this food type would have been recorded in the 2005 season had these kereru been caught earlier in the year. Fuchsia appeared to be the first ripe fruit available at the top of the reserve and was used as soon as it became available.

Kaikomako, pate and wineberry were all consumed over short periods and were eaten less often than other monitored species. One thing all these species have in common is that they produced small amounts of ripe fruit spread over time. This would make them less attractive than other monitored species that had peak periods of fruiting. It was interesting that more feeding observations were not made on pate as it is one of the few winter fruiting species. This may be because fruit is particularly small and plants are flimsy and low down in the sub-

canopy. I may also have been because most kereru in the lower valley were concentrating feeding on rohutu at this time of the year.

Mahoe was eaten when ripe fruit was available. Of all the monitored species mahoe is the most common fruit on the reserve and also had an extended fruiting season. Both these factors would account for its extensive use. Mahoe fruit contains high levels of both protein and glucose (Hill, 2003; Schotborgh, 2005) which could make it more attractive than species which are high in only one component. Mahoe also presented fruit in masses along branches, kereru moved systematically along each branch (pers. obs.) meaning that energy gain was high for little effort.

Ngaio, horopito and poroporo all attracted large loose flocks of kereru during their peak fruiting seasons. Kereru began feeding on ngaio and poroporo almost as soon as ripe fruit became available. Kereru on Purple Peak saddle were not observed until mid-way through the peak season but as horopito is a huge attraction it is likely that early-season feeding also occurred on this species. These species all produced large amounts of ripe fruit that was quickly removed by kereru.

It is likely that broom and tree lucerne flowers were preferred by tagged kereru over flowers of native species. Both these species were heavily used during their peak periods of flowering, which coincided with flowering of fuchsia and kowhai. Flowers alone did not appear to be sought out by kereru; rather they were eaten along with foliage. New leaves of broom, mahoe and tree lucerne were all consumed during peak leaf flush. Old and new leaves of broom, tree lucerne and kowhai were also eaten to supplement a dwindling fruit supply during winter when fewer leaves were present on plants.

5.4.3 Suggestions for enhancing kereru habitat on Banks Peninsula

A full list of species eaten by kereru in this study and also some kereru food species that occur on Banks Peninsula are in Appendix 4. Planting of any food species listed there is recommended to landowners wishing to enhance their property for kereru and other birds such as bellbird, silvereye (*Zosterops lateralis*), brown creeper (*Mohoua novaeseelandiae*) and tui (*Prothemadera novaeseelandiae*) (who are very occasional visitors to Banks Peninsula, but may be encouraged to re-establish if suitable habitat is available). Legumes and deciduous species are recommended as foods for kereru during winter and spring and can be important as

supplementary foods during other times of the year. Native fruiting species, especially those that were found to be of greater importance to kereru in this chapter, are of most value.

It is recommended that species be planted to extend fruit availability over as much of the year as possible. Because no native species and few introduced species currently fruit throughout late winter and spring on Banks Peninsula, legumes and deciduous species should be retained or planted to encourage kereru to remain in areas year round. These species may be more important for sustaining breeding populations than previously thought (Hill, 2003; Schotborgh, 2005). It would also be useful to plant native or introduced species which fruit during late winter and spring. It is not currently known whether kereru would prefer fruit during this time of year on Banks Peninsula.

Chapter 6

Home range and movements

6.1 Introduction

Accurate estimation of animals home range size and small and large scale movements, is an important prerequisite to better understanding distribution, resource use and behavioural ecology (Prendergast, 2006; Seaman & Powell, 1996; Swihart & Slade, 1985). The following studies of kereru ecology including estimation of home range size or movements have been carried out in New Zealand: Bell, 1996; Clout *et al.*, 1986; 1991; 1995; Hill, 2003; Pearson & Climo, 1993; Pierce & Graham, 1995; Schotborgh, 2005. These studies have shown that kereru movement and home range size is directly related to the location of food resources (Bell, 1996; Clout *et al.*, 1986; Clout *et al.*, 1991; Hill, 2003; Pearson & Climo, 1993; Pierce & Graham, 1995) and the availability of nest sites (Clout *et al.*, 1991; Schotborgh, 2005).

Home range size and movements within the home range can be used to help assess how vegetation characteristics of the landscape affect kereru. Home ranges of kereru in Whirinaki Forest Park, central North Island, varied between forest types (Hill, 2003). Home ranges that included large amounts of podocarp scrub were smaller than home ranges that included mixed podocarp-hardwood or dense podocarp forest (Hill, 2003). Schotborgh (2005) found that there was a significant difference in home range size between breeding and non-breeding seasons of kereru in the Lyttelton Harbour area. However there was no consistent trend - home range sizes increased for some kereru during the breeding season but decreased for others. Kereru had large Minimum Convex Polygon (MCP) areas but small core areas (calculated by cluster analysis) indicating that longer distances were travelled between sites but resources were used intensively within a site (Schotborgh, 2005). Frequency and distance of movements are also useful for determining seed dispersal patterns.

It was hypothesised that home range sizes in this study would be smaller than those found by Schotborgh (2005). The Hinewai Reserve study site is not as modified or fragmented as the Lyttelton Harbour study site. It was thought that because a larger proportion of the Hinewai Reserve study site is covered in native vegetation, kereru would travel less distance between preferred food and nest resources. This chapter will address the following questions and compare results with Schotborgh (2005):

1. What were annual home ranges of kereru captured in Hinewai Reserve?
2. Were there significant changes in home range size during the study period?
3. What were core areas within annual home ranges?
4. Over what distances did kereru travel, how frequent were these movements and at what times of the year were they made?
5. What does overlap of individual home ranges tell us about kereru interaction and resource use?

6.2 Methodology

6.2.1 MCP area, home range and core area calculations

For the purpose of this study the ‘home range’ of each kereru is defined as ‘the area repeatedly traversed by that individual’ (Kenward, 2001; Schotborgh, 2005). This definition includes excursive movements in which the individual spends time at the new location and returns, but excludes unidirectional dispersal (Kenward, 2001). It is also useful to know the entire area over which each kereru travelled and why kereru might be visiting these areas. For this reason a ‘MCP area’ was also calculated for all kereru in this study and is defined as ‘the area that is familiar to the individual’. Ranges VI software (Kenward *et al.*, 2003a) was used to calculate home ranges and MCP areas. Statistical significance was calculated using R 1.9.1 software (RDevelopmentCoreTeam, 2004).

6.2.1.1 MCP area calculation

The Minimum Convex Polygon estimator or ‘MCP’ is a minimum linkage estimator. The MCP area is a polygon that minimises the sum of link distances between edge locations (Kenward *et al.*, 2001). Location data is plotted on a grid and convex polygons with external angles greater than 180° are created around location points (Kenward *et al.*, 2003b). The smallest of these polygons is chosen as the MCP area.

MCP’s around the outermost locations have been the most common way of representing range size and shape in past studies (Kenward, 2001). However it has become apparent that biological understanding of an animal’s home range must include information about the intensity of use (‘core areas’ or ‘centres of activity’) of various parts of the home range (Kernohan *et al.*, 2001). Because they are mono-nuclear (made up of only one cluster of fixes), MCP’s have no internal structure and therefore give no indication about how intensively areas within the MCP are used (Kenward *et al.*, 2001). Another disadvantage of MCP’s is that they

are strongly influenced by peripheral fixes (Kenward *et al.*, 2001). Although many studies have used MCP as a home range estimator, MCP areas for kereru in this study do not represent home ranges. In this study MCP's using all locations are used as an indicator of the area that each kereru is familiar with.

6.2.1.2 Home range calculation

Cluster analysis was chosen for calculating home ranges in this study. This estimator is also a minimum linkage estimator but uses a different method to the MCP estimator. Cluster analysis is based on the assumption that animals probably route their initial visits to a new location from the nearest familiar one (Kenward, 2001). Clusters of location fixes or 'nuclei' are created by minimising the sum of nearest neighbour distances between fixes (Kenward *et al.*, 2001). Figure 6.1 illustrates this process with a simplified diagram. Nuclei are combined to make up the core area and home range. Cluster analysis is more fully described in Kenward (2001) and Kenward *et al.* (2003b). Figure 6.2 illustrates home range structure, and how this differs with MCP area, for kereru # 40.

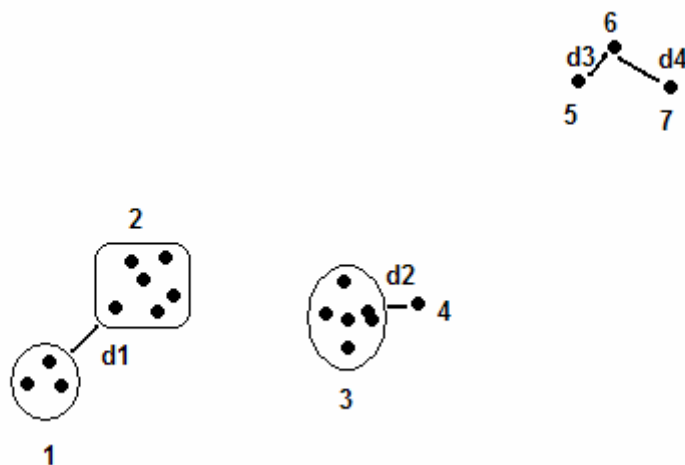


Figure 6.1 Simplified diagram of nuclei (cluster) formation. The three locations with the minimum sum of nearest-neighbour joining distances form the first nuclei (1). Two other nuclei form with next nearest-neighbour distances (2 and 3). Fixes 4-7 remain unassigned at this stage. The mean joining distance is then minimised by joining location 4 to nuclei 3, to add the smallest nearest neighbour distance (d2). Fusion of nuclei 1 and 2 will follow, because $d1 < d3 + d4/2$. Only then will addition of d3 and d4 form a new nuclei of locations (5-7) (Adapted from Kenward *et al.* 2001).

Cluster analysis was chosen for the following reasons:

- 1) It is a multi-nuclear estimator and therefore high-use areas can be defined.
- 2) If three or more locations occur at the same co-ordinates (this is common as kereru often return to the same tree) only one resolution cell is attributed to the site, unlike

density contouring where a ring is attributed that varies in size with the number of locations.

- 3) Use of this method is necessary if home ranges in this study are to be compared with Hill (2003) and Schotborgh (2005).

The outermost locations (outliers) were excluded from home range calculations; 95% of the locations were used to define the ‘objective core’ or home range boundary for each kereru. Although this is a subjective way of excluding outliers, 95% of locations have been used as the threshold in many studies (Kenward, 2001) including Hill (2003) and Schotborgh (2005).

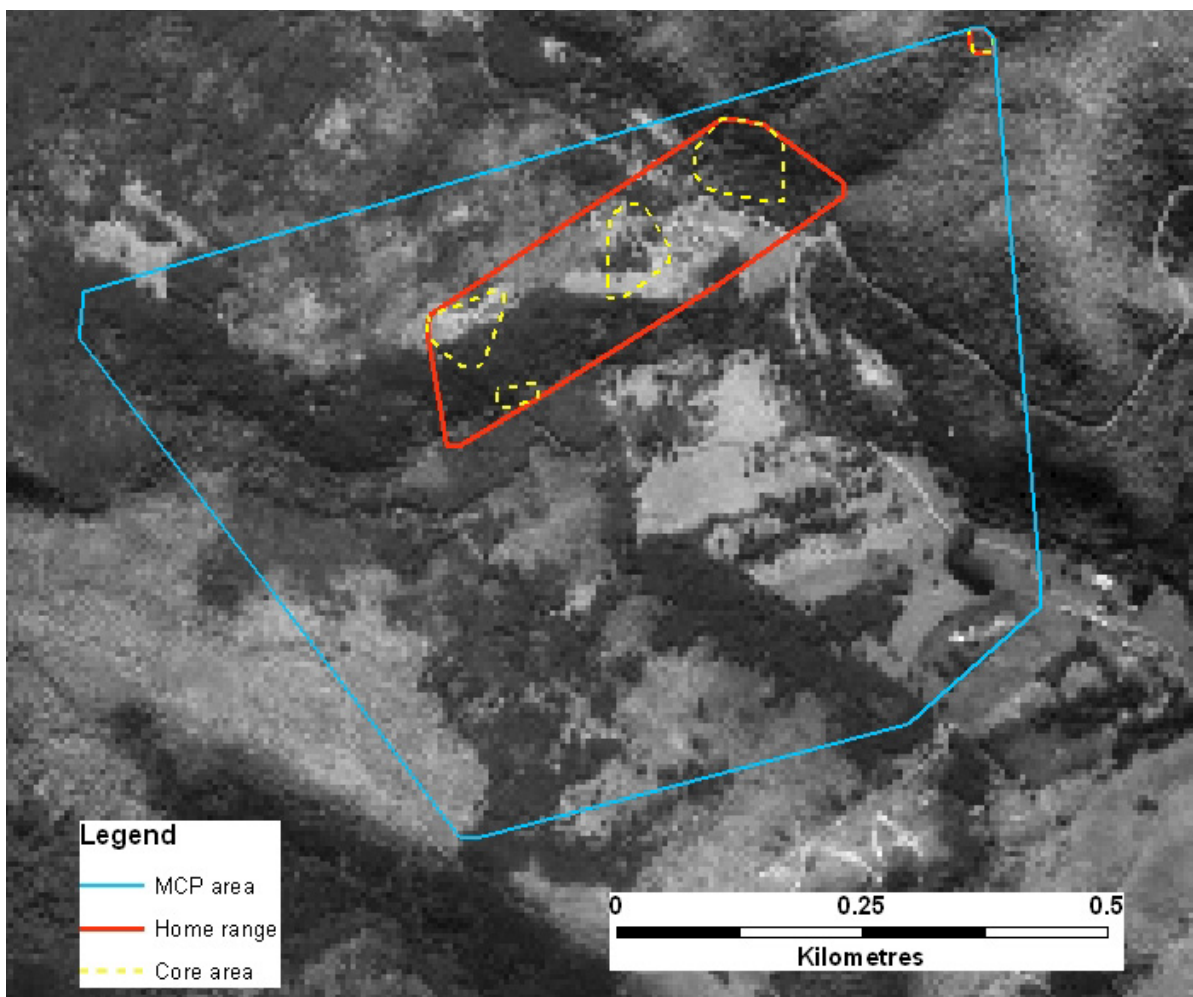


Figure 6.2. Aerial photo overlaid with the outer-MCP, home range and core area of kereru # 40. The home range consists of two nuclei (or clusters). Within the home range is the core area consisting of five nuclei.

Core areas were calculated using the ‘subjective core’ option in Ranges VI. Utilisation plots created in Ranges VI were inspected to determine what percentage of the location data should be included in the core area for each home range. The point on a utilisation plot at which outlying fixes begin to be excluded from the home range occurs when the graph drops sharply

and then declines less steeply (Kenward, 2001). This is called the point of ‘discontinuity’ or ‘inflection’ and the percentage of fixes at the inflection point is chosen as the core area. Figure 6.3 shows the utilisation plot for kereru # 42 with an inflection point at 85% of locations.

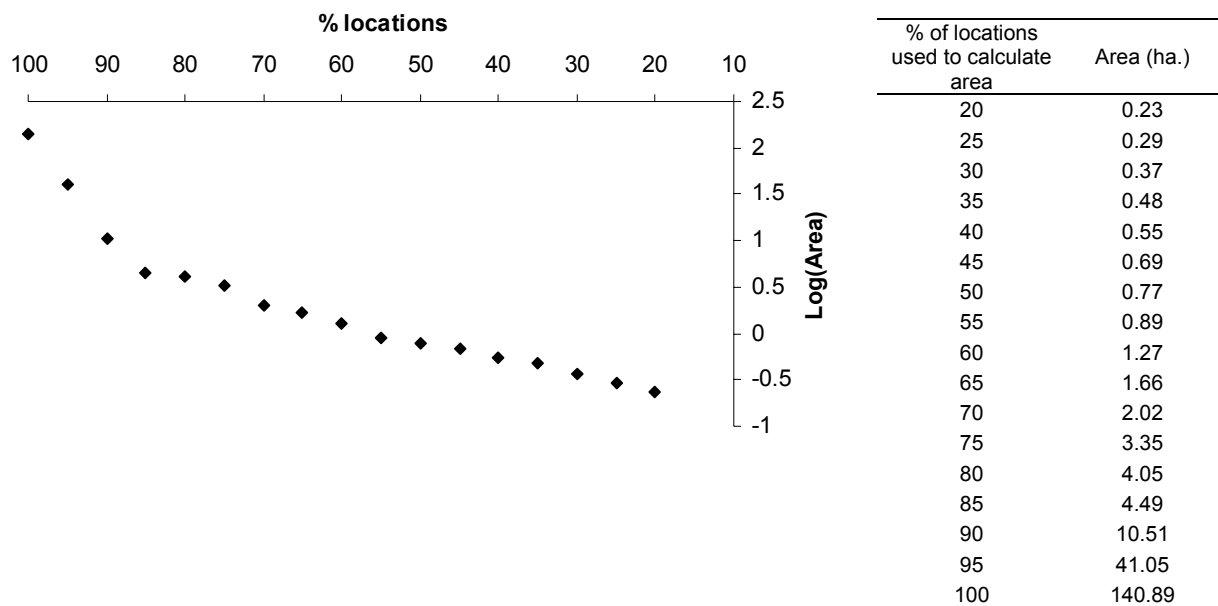


Figure 6.3. Utilisation plot used to determine the percentage of locations included in the core area.

6.2.1.3 Assessing stability of home ranges

Before home ranges were calculated, the minimum number of locations required to accurately estimate the home range of each kereru was assessed. This was done by creating incremental area plots (area of home range vs. number of locations) for each kereru using Ranges VI (Kenward *et al.*, 2003b). Home ranges for kereru whose incremental area plots did not show stability are included in the results but are assumed to be underestimates. For each kereru, the number of locations needed to reach MCP area and home range stability are shown in Appendix 5.

6.2.1.4 Comparing seasonal difference in home range size

Changes in home range size could not be compared between calendar seasons because there were not enough locations in each season for home ranges to reach stability. However I have assumed that changes in behaviour mark different phases or ‘seasons’ of the year for kereru. There were two distinctive changes of behaviour by kereru throughout the study period. These changes occurred between 1) the breeding season (August-March) and the non-breeding season and 2) when fruit was eaten (December-June) compared with when no fruit was eaten.

For all kereru a home range was calculated using data from field weeks when fruit was eaten and another home range calculated for field weeks when no fruit was eaten. For breeding kereru only, a home range was calculated using data from field weeks when breeding behaviour was exhibited and a separate home range calculated for field weeks when no breeding behaviour was exhibited. Data was not normally distributed so Wilcoxon's Rank Sum Test was used to detect differences between 1) breeding and non-breeding home ranges and 2) fruit eaten and no fruit eaten home ranges.

6.2.2 Home range overlap

Ranges VI software was used to calculate static interaction (overlap of two home ranges at any time as opposed to 'dynamic overlap' which is overlap of home ranges at the same time) between pairs of kereru of both sexes (male-female, male-male & female-female). Overlap could not be compared between sexes, as sex was known for only eight kereru. The proportion of overlap between all individuals was calculated separately for the fruit-eating and non-fruit eating period and displayed in a matrix. A summary for each season was also created in Ranges VI from the matrix files.

6.2.3 Timing and extent of movements

Clout *et al.* (1991), Hill (2003) and Schotborgh (2005) separated movements made by kereru into two to three classes depending on distance travelled and the type of movement. These classes are:

- 1) short-distance movements (<1500 m)
- 2) long-distance movements (>1500 m) in which the kereru returned to the original location within the study period and
- 3) long-distance movements (>1500 m) in which the kereru did not return to the original location (uni-directional dispersal).

Distances between consecutive locations were calculated using Pythagoras's Theorem

($a^2+b^2=c^2$) for each kereru. Movements were placed into one of the following distance classes:

0-250 m, 251-500 m, 501-1000 m, 1001-1500 m and >1500 m and the proportion of movements made in each category was calculated. A summary table was created of the timing of long-distance movements made by each kereru.

6.3 Results

6.3.1 Estimation of annual home ranges and core areas

6.3.1.1 Hinewai Reserve study site

Twelve kereru were located in every field week during the study period. Using cluster analysis, home range size could be reliably estimated for eight kereru but could not be reliably estimated for four kereru (Table 6.1). Incremental area curves showed stability of MCP areas for all kereru (Table 6.1).

MCP areas ranged from 20 to 499 ha and home range sizes ranged from 1.8 to 40.1 ha (mean=15.9 ha). Kereru used between 6 and 42 % of the area familiar to them for their home ranges.

Table 6.1. Estimates of MCP area and annual home ranges (HR) and core areas (CA) for kereru at the Hinewai Reserve study site and Akaroa study site. See 6.2.1 for explanation of these terms.

Hinewai

Keruru no.	MCP area (ha)	Home Range (HR)		Core Area (CA)		Nuclei	
		Clusters (ha)	Clusters as a % of MCP	Clusters (ha)	% of HR	HR	CA
40	52	5.9	11	1.6	27	2	5
42*	464	28.4	6	4.5	16	4	11
44	71	10.1	14	1.5	14	3	5
46*	112	10.1	9	1.6	15	3	4
48*	103	19.5	19	1.3	6	5	10
50*	28	6.5	24	1.7	26	3	8
56	82	8.3	10	1.1	14	4	5
58	124	18.0	14	1.6	9	3	11
60 [†]	20	1.8	9	0.3	19	1	6
62	499	40.1	8	2.1	5	1	5
64	75	31.5	42	4.6	15	2	4
68 [†]	102	10.2	10	2.7	27	8	8

Akaroa

Keruru no.	MCP area (ha)	Home Range (HR)		Core Area (CA)		Nuclei	
		Clusters (ha)	Clusters as a % of MCP	Clusters (ha)	% of HR	HR	CA
52	182	45.2	25	2.5	5	1	9
54	68	27.6	40	0.3	1	1	2
66*	183	15.3	8	1.1	7	2	8

* Incremental-area curve did not show stability of home range. Home range sizes for these kereru are likely to be underestimates.

[†] 60 and 68 were found dead (of unknown causes) in July

6.3.1.2 Akaroa study site

Two kereru were located every week throughout the study period. One kereru (66) could not be located during the last three weeks of the study period. Incremental area curves did not show home range stability for kereru 66 (Table 6.1). All incremental area curves of MCP areas showed stability (Table 6.1), however as kereru 66 was missing for several weeks the MCP area for this kereru may be an underestimate.

MCP areas ranged from 68 to 183 ha (Table 6.1). Home ranges ranged in size from 15.3 to 45.2 ha (mean=29.3 ha). Kereru used between 8 and 40% of the area familiar to them as their home range.

6.3.1.3 Correlation between core area and home range size

Core Areas ranged in size from 0.3 to 4.6 ha (mean=2 ha) at the Hinewai Reserve study site and 0.3 to 2.5 ha (mean=1.3 ha) at the Akaroa study site (Tables 6.1). Core areas comprised between 5 and 27% and 1 and 7% of the home range respectively. There was a significant positive correlation between home range size and core area size for the Hinewai Reserve site (linear regression (lm), $P=0.0224$). No significant relationship was found for the Akaroa study site; perhaps due to the small sample size any difference may not have been detected.

The number of nuclei in home ranges and core areas ranged from 1 to 8 and 4 to 11 respectively for the Hinewai Reserve study site (Table 6.1). For the Akaroa study site the number of nuclei ranged from 1 to 7 and 2 to 9 respectively (Table 6.1). There was no correlation between the number of nuclei and home range or core area size (linear regression (lm), $P=0.66$; $P=0.6$).

6.3.1.4 Comparison of annual home range and core area size, and the number of nuclei in ranges, with the Lyttelton Harbour study site (Schotborgh, 2005)

At the Lyttelton Harbour study site, mean home range size and core area size were 8 ha and 0.08 ha respectively (Schotborgh, 2005). Home range sizes of kereru in the Hinewai Reserve study site were significantly larger than for kereru in the Lyttelton Harbour study site (Schotborgh, 2005) (t-test, $P=0.0095$). Core areas of Lyttelton Harbour kereru were much smaller than those of kereru from the Hinewai Reserve study site (Wilcoxon rank sum test, $P=0.000017$).

For the Lyttelton Harbour study site, the number of nuclei ranged from 2 to 7 in home ranges and 4 to 22 in core areas (Schotborgh, 2005). There was no significant difference between study sites in the number of nuclei in home ranges (t-test, $P=0.34$) but the number of nuclei in core areas of kereru in the Hinewai Reserve study site was significantly less than for Lyttelton Harbour kereru (t-test, $P=0.00004$). Roughly the same numbers of home ranges at each study site were unstable so underestimates were not likely to affect statistical significance.

6.3.2 Estimation of seasonal home ranges

It was found that home range size increased when kereru were feeding on fruit ('fruit eaten season') compared to when no fruit was eaten ('no fruit eaten season'). It is interesting to note that there was no significant difference in home range size between breeding and non-breeding seasons for breeding kereru (Wilcoxon Rank Sum Test, $P=0.4$) (Table 6.2). Only the 'fruit-eaten season' and 'no-fruit-eaten season' will be referred to as 'seasonal home ranges' in further results and discussion.

Table 6.2. Breeding and non-breeding home ranges of breeding kereru.

Kereru no.	sex	Breeding		Non-breeding	
		Area (ha)	Nuclei	Area (ha)	Nuclei
40	f	2.4	3	4.8	1
42	f	14.5	4	4.0	3
44	f	5.3	4	8.2	2
46	m	19.7	2	5.3	2
50	m	2.0	6	4.4	2
58	f	9.4	4	6.9	2
62	f	3.7	2	31.8	1
66	f	3.7	1	10.5	2

6.3.2.1 Seasonal home ranges of kereru in the Hinewai Reserve study site

Home ranges of four kereru could be reliably estimated for the fruit-eaten and no-fruit-eaten seasons (Table 6.3). For two kereru (# 50 and 56) home ranges could not be reliably estimated for either season (Table 6.3). For two kereru that died, only home ranges for the fruit eaten season could be reliably estimated.

Home ranges during the fruit-eaten season ranged in size from 1.8 to 33.7 ha (mean=12.4 ha) (Table 6.3). When no fruit was eaten by kereru, home range size ranged from 1.2 to 12.3 ha (mean=5.8 ha). Home ranges during the fruit-eaten season were significantly larger than during the no fruit eaten season (Wilcoxon Rank Sum Test, $df=9$, $p=0.02$).

Table 6.3. Estimates of seasonal home ranges of kereru in the Hinewai Reserve study site and Akaroa study site using cluster analysis.

Hinewai

Kereru no.	Fruit-eaten		No-fruit-eaten	
	Area (ha)	Nuclei	Area (ha)	Nuclei
40	3.0	3	1.2	4
42	33.7	1	12.3	5
44	14.5	2	1.8*	4
46	7.1*	2	5.2	3
48	11.8	5	8.9*	2
50	2.9*	3	1.7*	4
56	4.5*	4	2.8*	3
58	13.5	2	4.8	2
60†	1.8	1	-	-
62	33.0	1	2.2*	4
64	8.2	3	7.3	2
68†	14.5	6	-	-

Akaroa

Kereru no.	Fruit-eaten		No-fruit-eaten	
	Area (ha)	Nuclei	Area (ha)	Nuclei
52	30.8	1	1.8*	5
54	19.0	1	1.2	1
66	6.3*	2	4.3	3

* The incremental-area curve showed no stability. Size of these home ranges is likely to be underestimated.

† No data was available during the no-fruit-eaten season as these kereru died

6.3.2.2 Seasonal home ranges of kereru in the Akaroa study site

Home ranges could be reliably estimated in both seasons for kereru # 54 and in one season for kereru # 52 and # 66 (Table 6.3.). The period that kereru # 66 could not be located was during the fruit-eaten season.

Home range size in the fruit-eaten season ranged from 6.3 to 30.8 (mean=18.7 ha) and decreased to between 1.2 and 4.3 ha (mean=2.4 ha) when no fruit was eaten (Table 6.3). No significant difference was found for the Akaroa site (Wilcoxon Rank Sum Test, P=0.1) or between sites (Wilcoxon Rank Sum Test, P=0.69), perhaps because of the small sample size.

6.3.3 Home range overlap

The number of times any two kereru overlapped their home ranges was considerably greater when kereru were eating fruit compared with when no fruit was eaten but the extent to which home ranges overlapped with each other was slightly smaller (Table 6.4).

Table 6.4. The number of times any two kereru overlapped home ranges and the average proportion of home range overlap for the fruit-eaten and no-fruit-eaten seasons.

	Total number of overlaps	Average proportion of overlap (%)
Fruit eaten	70	15
No fruit eaten	22	21

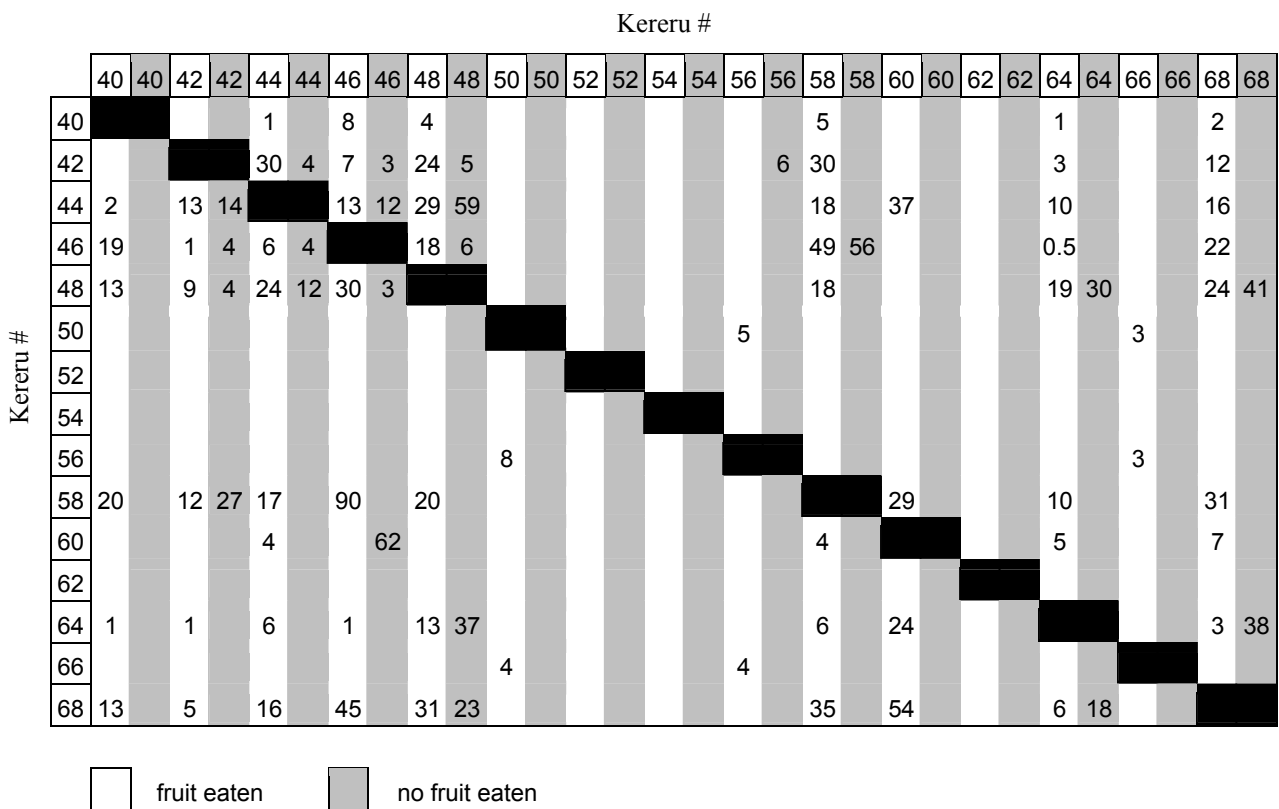


Fig. 6.4 The proportions (%) of home range overlap between all tagged kereru for each season. Kereru # 52, 54 and 66 were residents of Akaroa; kereru # 62 resided in Sleepy Bay gully. All other kereru were residents of Otanerito Valley.

Home ranges of tagged kereru in Akaroa did not overlap at all (Fig. 6.4). The resident Sleepy Bay gully kereru did not overlap its home range with any tagged kereru in Otanerito Valley (Fig. 6.4). However, tagged kereru in Akaroa were seen to overlap home ranges with untagged kereru; flocks of 20-30 kereru were seen feeding on poplar and holly. Only Akaroa resident kereru # 66 overlapped its home range with kereru from the Hinewai Reserve study site (Fig. 6.4); this occurred when horopito was fruiting. Home range overlap was most common for Otanerito Valley kereru (Fig. 6.4).

The greatest number of home range overlaps occurred in the 0-10 and 10-20% categories for both seasons (Fig 6.5). The number of overlaps declined as the proportion of overlap between ranges increased (Fig 6.5). The highest proportion of overlap (90%) occurred in the fruit-eaten season between the only tagged breeding pair (# 58-46).

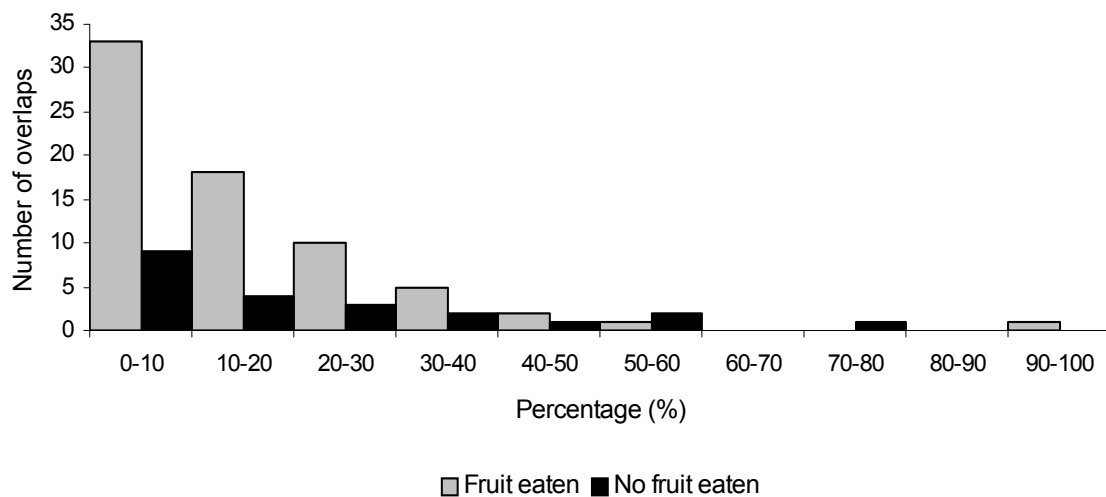


Fig 6.5. Number of home range overlaps occurring in each percentage category for kereru at both study sites.

6.3.4 Timing and extent of movements

Long distance movements (>1.5 km) occurred throughout the year (Fig 6.6). Significantly more long distance movements were made during the fruit-eaten season than when no fruit was eaten (Mann-Whitney U-test, P=0.02). Six kereru made long distance movements during the study period. The greatest number of long distance movements was made by kereru # 58. Most of these were made during the fruit-eaten season.

Her partner # 46 also made numerous long distance movements during this period. Three residents of Akaroa (# 52, 54 and 66) and one of Sleepy Bay (# 62) were caught near Purple Peak Saddle and returned to Akaroa in April (Fig 6.6). Kereru # 62 also made several excursions from Sleepy Bay gully into adjacent Stony Bay valley during January and February.

Table 6.5. The proportion of movements made in each distance category at the Hinewai Reserve and Akaroa study sites during the fruit-eaten and no-fruit-eaten seasons.

Hinewai

	Distance categories				
	0-250 m	251-500 m	501-1000 m	1001-1500 m	>1500 m
Fruit-eaten	0.65	0.15	0.12	0.04	0.04
No-fruit-eaten	0.68	0.18	0.10	0.02	0.01

Akaroa

	Distance categories				
	0-250 m	251-500 m	501-1000 m	1001-1500 m	>1500 m
Fruit-eaten	0.84	0.04	0.06	0.04	0.02
No-fruit-eaten	0.91	0.09	0.00	0.00	0.00

6.4 Discussion

6.4.1 Home ranges and core areas

Comparisons of home range size between studies can be difficult because of variability in methodology and also in estimators and software programmes used. Bell (1996) used MCP area as an indicator of kereru home range size and Pierce and Graham (1995) did not include the method of estimation in their report. Clout *et al.* (1991) estimated movement of kereru away from the study site but did not estimate home range size or structure. Hill (2003) also used cluster analysis but sampled kereru locations every 10 days over several years. Results from these studies are useful to help interpret results of the present study but have not been used for direct comparison. Direct comparison was carried out with Schotborgh (2005) as these two studies were designed to be compatible. Schotborgh (2005) investigated home ranges and movement of kereru at two study sites in the Lyttelton Harbour area. Fragments of suitable kereru habitat were small and were surrounded by large areas of poor quality habitat such as pasture. The Orton Bradley Park study site was a farm park used for recreational and farming activities and the Church Bay study site was a small residential area surrounded by farmland. Both study sites contained small fragments of regenerating native forest.

It was expected that home ranges of kereru in Otanerito Valley would be smaller than in Lyttelton Harbour, however the reverse was true - home ranges and core areas were significantly larger. Surprisingly, home ranges and core areas of Akaroa kereru were more

similar in size to kereru in the Hinewai Reserve study site than to Lyttelton Harbour. This indicates that Akaroa may share more habitat characteristics with these areas than with the Lyttelton Harbour study site. Akaroa had a greater number of native forest fragments in and around the township compared with the Lyttelton Harbour study sites. It is also possible that Akaroa had a higher proportion of native species in residential gardens compared with the Lyttelton Harbour study sites.

Hill (2003) reported that home ranges of kereru in Whirinaki ranged from 14 to 704 ha with a mean home range size of 163 ha. These home ranges were considerably larger than for both Hinewai Reserve and Lyttelton Harbour study sites. There is a trend from very small home ranges and core areas in the highly modified and fragmented landscape of Lyttelton Harbour to large home ranges in the continuous native forest habitat of Whirinaki forest. The Hinewai Reserve study site falls in the middle with more native forest and less introduced species than Lyttelton Harbour, but less native forest and more introduced species than Whirinaki Forest Park.

Core areas of Lyttelton Harbour kereru were significantly smaller and the numbers of nuclei in core areas significantly higher than for kereru in this study. This may indicate intensive use of many small areas by Lyttelton Harbour kereru and a more even spread of feeding effort over larger areas by kereru in this study. Unlike the Lyttelton Harbour study site where core areas were all less than 4%, core areas of kereru in Otanerito Valley and Sleepy Bay increased with home range size. The sample size for Akaroa kereru was not large enough to detect a relationship. This means that kereru in Lyttelton Harbour used a very small percentage of the area available to them for foraging.

It is unlikely home range size was a direct indicator of overall habitat quality of study areas for this study or Schotborgh (2005). While small home ranges in Lyttelton Harbour indicated that patches of high quality habitat were available, it did not reflect the quality of the study area as a whole. Not having an understanding of the overall density of kereru at each study site was a confounding factor. In the Lyttelton Harbour study site, large areas of poor habitat supported no kereru. These areas were interspersed by small patches of high quality habitat that only supported small numbers of kereru, but kereru density in these patches was high (Schotborgh, 2005). This is likely to have resulted in a lower overall density of kereru compared with the Hinewai Reserve study site where high quality resources were more uniformly distributed over larger areas.

The distribution of high quality food sources is likely to have caused the observed differences in home range and core area size between localities. If this is the case, there are three scenarios that are likely to have caused this variation:

- 1) kereru in Lyttelton Harbour were restricted by patchy and/or limited distribution of high quality food sources
- 2) habitat in the Hinewai Reserve study site is poor causing kereru to move over larger areas to get food
- 3) kereru in this study moved over larger areas to make use of a more uniform spread of high quality foods offering different nutritional characteristics (Dijkgraaf, 2002) .

Assessment of results from this study and previous studies suggests that scenarios 1 and 3 are the best explanations.

Kereru will expand their home ranges to seek out preferred food species (Bell, 1996; Clout *et al.*, 1991; Hill, 2003; Pierce & Graham, 1995). In this study native fruit appears to be preferred over foliage and exotic fruit species. If fruiting is asynchronous among and between species spread over a large area there is the potential for home ranges to also be large. Home ranges for kereru in this study were significantly larger during the season fruit was eaten. This indicates that kereru travel further afield when eating fruit and are more sedentary when they are eating foliage. Hill (2003) also found that home ranges of kereru in Whirinaki Forest were smaller when kereru were eating foliage. Foliage was more accessible to kereru at all sites and this could explain why kereru in Lyttelton Harbour, who relied more on foliage, were more sedentary.

Unlike Schotborgh (2005), in this study there was no difference in home range size between breeding and non-breeding seasons. Schotborgh (2005) suggested that for some kereru suitable nest sites were located away from foraging areas causing kereru to travel further while breeding. Other kereru focused their foraging around nest sites (Schotborgh, 2005). Potential nest sites for kereru in the Hinewai Reserve study site were abundant and all relatively close to foraging areas.

6.4.2 Distance travelled

The fruit-eaten and no-fruit-eaten seasons were used to put long-distance movements into context rather than breeding and non-breeding seasons. Although the breeding and fruit-eaten seasons overlapped, an increase in long distance movements did not occur until fruit became available in summer even though the breeding season commenced in August. Breeding kereru

fed on broom close to the nest until fruit became available; only then did they start making regular long distance movements to feed on fruit. Birds such as hihi (*Notiomystis cincta*) and albatross (*Phoebastria* sp.) are known to eat close to the nest during incubation and then further away during the nestling stage (I. Castro, *pers. comm.*). Kereru brood in shifts so one parent is always on the nest. This means that kereru can go further a field while foraging because the egg is not vulnerable to cooling.

Kereru from the Hinewai Reserve study site made no excursions >5 km and no daily movements >2 km. One lower valley kereru made a short return trip to the top of Otanerito Valley but tagged kereru at the top of the valley did not come down into the lower valley. This indicates that there is limited movement of kereru between the upper and lower valley. The distances moved were similar to movements made by kereru in Wenderholm, north of Auckland, and Maungatapere, near Whangerei (Bell, 1996; Pierce & Graham, 1995). Both of these sites consist mainly of fragmented native forest with many large-fruited tree species such as puriri, tawa (*Beilschmiedia tawa*) and karaka, which provide fruit year round. It is theorised that year round fruit production is the reason why home ranges and movements were smaller than for other studies (Pierce & Graham, 1995). While the Hinewai Reserve study site does not have fruit available year round, I suggest an abundance of kowhai, broom and willow means that kereru do not have to move far to find nutritious foods during winter and spring.

None of the kereru at the Hinewai Reserve site left the valley in search of food during the study period. Kereru # 58 and # 46 made the most long-distance movements. Nearly all were made while the pair was feeding their chick pigeonwood fruit collected from coastal gullies, 1.7 km from the nest. Kereru in Akaroa and Sleepy Bay gully (# 52, 54, 66 and 62) were captured feeding on horopito in Hinewai Reserve in autumn indicating that there may be a shortage of native fruit in their normal range during this time. Kereru # 62 also made trips into neighbouring Stony Bay in mid to late summer to feed on fruit of pigeonwood and ngaio, which were not present in its normal range. Kereru # 66 could not be located in any surrounding areas in the final weeks of the study period. It is not known whether this kereru dispersed to another part of the peninsula or if the transmitter failed.

Kereru are important dispersers of the seeds of native fruiting species, especially those >10 mm in diameter (Clout & Hay, 1989). As seeds are thought to pass through the gut in 1-2.5 hours (Clout & Tilley, 1992), there is a good chance seeds will be dispersed away from the parent

plant. Schotborgh (2005) and the present study suggest seeds are most likely to be dispersed less than 250 m from the parent plant. A greater number of seeds would be dispersed in the 250-1000 m range in the Hinewai Reserve study site than in the Akaroa and Lyttelton Harbour sites. In a moderately fragmented habitat like Otanerito Valley this would result in seeds being dispersed between forest fragments. In a highly-fragmented habitat most seeds would be deposited within the same forest fragment as the parent tree. In Akaroa movement by kereru possibly increases the spread of fruiting weed species such as hawthorn and cotoneaster. These species often grow on native forest margins and kereru feeding on them usually move into the forest to rest; both of these species were seen in light gaps within forest fragments (pers. obs.).

Despite having smaller home ranges, many Lyttelton Harbour kereru had larger MCP areas than kereru in this study. Lyttelton Harbour kereru also made more than twice the number of long distance movements (>1500 m) than kereru in this study. The level of habitat fragmentation at each study site almost certainly influenced excursive movements. Greater fragmentation may mean that less required resources occur in a small area, requiring kereru to travel further to search for prospective food sources or find preferred species.

6.4.3 Home range overlap

Home range overlap indicated the extent to which pairs of kereru and all kereru in each study site shared resources. Because of the very small sample size in Akaroa, little information could be gained from the lack of home range overlaps between these kereru. In Otanerito Valley there were a greater number of overlaps between pairs of kereru during the season fruit was eaten compared to when no fruit was eaten. This is not surprising considering that kereru flocked to fruiting species such as poroporo, ngaio, pigeonwood, rohutu and horopito which were fairly localised. Home ranges of kereru during this season were larger, again giving more opportunity for home range overlap. Kereru also flocked to clumps of broom during the season when no fruit was eaten, however broom is spread over wider areas than the above species therefore there was less chance of overlap by tagged kereru. Kereru were more sedentary whilst feeding on foliage and many tended to feed in the same area for months on end, reducing the chance that home ranges would overlap.

Most tagged kereru shared only small proportions of their home range with other tagged kereru. However, sample sizes of radio-tagged birds at each study site were small, and there appeared to be large numbers of untagged kereru in both the Hinewai Reserve and Akaroa

study sites (pers. obs.). It is likely that some tagged kereru shared higher proportions of their home ranges with untagged kereru. Large flocks of between 40-100 kereru were observed during peak fruiting of horopito and poroporo and new growth of broom (pers. obs.). Regular observations of flocks of kereru at these times of year suggest that these seasonal influxes occur every year (H. D. Wilson, *pers. comm.*). The highest proportion of overlap occurred between # 46 and 58, a breeding pair where both kereru were tagged. This pair shared the area around the nest but also independently fed in the same area, for example when one kereru was incubating.

6.4.5 Conclusions

Distribution of quality food sources is likely to have caused the observed differences in home range and core area size between localities. Kereru in this study used food sources spread over larger areas when fruit was eaten. As there was no shortage of native fruit during this time kereru had the choice to move between preferred food sources as they became available. Kereru prefer native fruit over foliage; # 46 and 58 regularly travelled long distances to feed their chick native fruit even though foliage of kowhai and broom was readily available. The fact that kereru were using larger areas to forage on fruit indicates that small home range size does not necessarily indicate better quality habitat.

Lyttelton Harbour kereru bred successfully (Schotborgh, 2005), indicating that there was enough suitable foods for these kereru. However some kereru had to travel large distances in search of food. Disparity of core area size vs. home range size means that Lyttelton Harbour kereru were only using very small parts of their home range. The proportion of overlap by Lyttelton Harbour kereru was higher compared with this study suggesting Lyttelton Harbour kereru were sharing a higher proportion of resources.

The level of habitat fragmentation in Lyttelton Harbour appears to limit kereru to small areas. These areas may support the few kereru that reside there but the nature of the landscape would limit carrying capacity per hectare. Larger fragments of native forest and a mix of native and introduced vegetation appeared to allow a higher carrying capacity for kereru in Otanerito Valley and Akaroa.

There was limited movement of tagged kereru between upper and lower Otanerito Valley. Tagged kereru moved to some extent within their half of the valley depending on availability

of preferred food sources. Flocks of kereru in the lower valley appear to be concentrations of kereru from the immediate vicinity whereas flocks of kereru at Purple Peak Saddle contained kereru from outside of Otanerito Valley. Combined with the fact that kereru have fairly small home ranges, this knowledge gives us some idea of how dynamic the kereru population within Otanerito Valley is. If population trend monitoring were to be carried out, migration and flocking behaviour of kereru at certain times of the year would need to be taken into consideration when designing suitable methodology. Home ranges are used in Chapter 7 to calculate seasonal habitat use and habitat selection within ranges.

Chapter 7

Habitat use

7.1 Introduction

Habitat use is site specific to some extent, dependent on landscape characteristics and the vegetation types available. Previous studies investigating vegetation use by kereru and parea (*Hemiphaga chathamensis*) have been carried out (Clout *et al.*, 1986; Crossland, 1996; Dunn, 1981; Hill, 2003; Pearson & Climo, 1991, 1993; Ridley, 1998; Schotborgh, 2005), but of these studies only Ridley (1998) and Schotborgh (2005) include quantitative measures of habitat use by kereru. Only one study of habitat use by kereru has been carried out on Banks Peninsula (Schotborgh, 2005). In order to enhance habitat for kereru on Banks Peninsula it is necessary to know what vegetation communities and plant species are preferred as foraging, resting and nest sites. Kereru on Banks Peninsula make use of native, exotic and mixed vegetation communities. It is currently unknown whether use of these habitat types reflects preference by kereru or availability.

Key food species' are an important consideration when planning habitat enhancement for kereru. However habitat selection is also based on other important habitat characteristics such as suitable roost and nest sites (Cody, 1985). Observations of activity patterns of kereru in Waihi bush showed that a high percentage of time is spent resting (Ridley, 1998). This is supported by data from a study of parea by Pearson and Climo (1991). Pearson and Climo (1991) found that the use of hoho (*Pseudopanax chathamicus*), mahoe, karaka, karamu and Chatham Island matipo (*Myrsine chathamicus*) by parea (Chatham Island pigeon) was proportionally greater than the availability of these species. Not all preferred species were used for foraging; for instance karaka was used only for loafing and preening (Pearson and Climo, 1991).

It is thought that kereru prefer mixed podocarp-broadleaf forests with high species diversity and complex structure (Higgins & Davies, 1996). As a result of extensive habitat modification, selection of vegetation types by kereru on Banks Peninsula may have changed since human settlement. Suburban gardens, areas containing introduced trees and regenerating native forest are habitats commonly inhabited by kereru today. This chapter investigates use and selection

of vegetation communities by kereru and use of plant species for non-feeding activities within the Hinewai Reserve study site.

7.2 Methodology

As a detailed vegetation map of the Akaroa study site was not available, data from tagged kereru who resided in Akaroa was not used for analysis.

7.2.1 Digitisation of a vegetation map of the Hinewai Reserve study site

7.2.1.1 Digitising vegetation types within Hinewai Reserve

A map showing the main vegetation types within Hinewai Reserve was obtained from Hugh Wilson, manager of Hinewai Reserve. Using the map, my knowledge of the reserve and an aerial photograph of the study site, vegetation types were digitised by overlaying polygons representing areas of each vegetation type onto the aerial photograph in ArcMap™ (ArcGIS 9) (Minami *et al.*, 1999-2004).

7.2.1.2 Digitising vegetation types outside the boundary of Hinewai Reserve

Observations made during fieldwork were used to define the main vegetation types in areas outside of Hinewai Reserve that were used by kereru. Using my knowledge of the study site and features on the aerial photograph, vegetation types were digitised by overlaying polygons representing areas of each vegetation type onto the digital photograph in ArcMap™.

7.2.1.3 Creation of the final vegetation map

Polygons of each vegetation type were merged into one shapefile in ArcMap to create the final vegetation map. This map was imported into Ranges VI (Kenward *et al.*, 2003b) and the area of each vegetation type calculated using the ‘Habitat content of a whole map’ option and expressed as a proportion of the total map area. Dominant plant species in each vegetation community were determined from personal observations and Wilson (1994).

7.2.2 Calculation of the availability of each vegetation type within home ranges

To simplify analysis, four of the vegetation types included in the vegetation map were pooled into two categories on the basis of similarity of habitat type and use by kereru. ‘Kanuka scrub’ and ‘coastal scrub’ were merged to form a ‘native scrub’ category and ‘emerging natives’ and ‘gorse/broom’ were merged under the label ‘gorse/broom’.

Kenward (2001) suggests that for location-within-range associations, habitat availability can be calculated using either outer-MCPs (100% of location data) or home ranges containing 95% of locations. I chose to use home ranges excluding outliers to estimate availability for the following reasons:

- 1) Use of MCP areas showed avoidance of habitat types that kereru moved out of their home range to utilise, when in fact these habitat types were obviously important.
- 2) It is more useful to understand relative importance of habitats which were included in daily movements, rather than in areas which were flown over by kereru on route to destinations outside of the home range.

Home ranges calculated using cluster analysis (see chapter 6) were used to estimate the availability of each vegetation type to each kereru. Analysis was done in Ranges VI using the ‘Habitat content in ranges’ option. Separate analyses were done for annual and seasonal home ranges (defined in chapter 6). Availability of each vegetation type was expressed as a percentage of the total home range area for each kereru. Adjoining polygons overlapped a little bit or were not flush in some areas of the vegetation map. This caused the area of some vegetation types in kereru home ranges to be slightly over/underestimated, as a result percentages sometimes add to more or less than 100.

7.2.3 Calculation of use of each vegetation type by kereru

Use of each vegetation type by each kereru was calculated using location data obtained from radio tracking (see chapter 3). The ‘Habitat at locations’ option in Ranges VI was used to calculate the number of location fixes within each vegetation type. Results are expressed as a percentage of the total number of fixes for each kereru per vegetation type. Percentages sometimes add to slightly more or less than 100 (see 7.2.2 for explanation). Separate analyses were done for annual and seasonal data.

7.2.4 Selection of vegetation types by kereru

The ‘Habitat preference in ranges’ option in Ranges VI was used to calculate Jacob’s Index values (D) (Jacobs, 1974) for each vegetation type using the following formula:

$$\frac{(U - V)}{[U + V - 2UV]}$$

U=Proportion used
V=Proportion available

Use and availability were calculated as shown in 7.2.2 and 7.2.3 and expressed as proportions.

The Jacob's Index is a measure of preference or avoidance of particular vegetation types, values range between -1 and +1 with values above 0 indicating preference and values below 0 indicating avoidance. Values close to 0 indicate that the vegetation type was used by kereru in proportion to its availability. Separate analyses were done for annual and seasonal data of each kereru.

There was no way to test how significant each selection value was, so it was decided that arbitrary thresholds of -0.5 and +0.5 be used. These thresholds exclude marginal results where kereru used vegetation types only slightly more or less than they were available. Values between these thresholds were not considered to be clear indications of preference or avoidance. Values ≤ -0.5 or ≥ 0.5 are highlighted to show clear preference or avoidance of a vegetation type. Only values that met the thresholds were referred to as 'preferred' or 'avoided'.

Not all kereru had all vegetation types available to them; therefore it was not possible to average over all tagged kereru to determine overall selection of each vegetation type. The following calculations were used as alternative ways to determine overall selection:

7.2.4.1 Changes in the selection of each vegetation type

This calculation was carried out to provide a standard set of values for determining how preference and avoidance of vegetation types changed throughout the study period. The number of selection values ≥ 0.5 for a particular vegetation type was divided by the total number of selection values calculated for that vegetation type. The number of selection values ≤ -0.5 for the same vegetation type was also divided by the total number of selection values calculated for that vegetation type. These calculations were carried out for all vegetation types; separate analyses were done for annual and seasonal data.

7.2.4.2 Selection of vegetation assemblages

All the vegetation types in the Hinewai Reserve study site (defined in 7.3.1) were grouped into two categories ('native' and 'introduced') on the basis of whether native or introduced species were dominant in the community. Another two categories ('forest' and 'non-forest') were created on the basis of whether vegetation types were predominantly forest (native or exotic forest with a canopy >5 m in height) or non-forest (pasture and scrub). Grouping vegetation types in this way meant that each kereru now had all categories available to them. Use and

availability of each category was averaged over all kereru for the study period and each season. Preference was calculated using the Jacobs Index. Comparisons between 1) native vs. non-native and 2) forest vs. non-forest were shown using bar graphs.

7.2.5 Plant species used for non-feeding activities

During radio-tracking of kereru I recorded the plant species used for roosting, loafing or preening (see 3.3.1 for details). The number of times each plant species was used for these activities was tallied. The tally for each plant species was then divided by the total number of observations to give the proportion of non-feeding observations recorded for each plant species. Plant species used for nesting were also recorded.

7.3 Results

7.3.1 Vegetation composition of the Hinewai Reserve study site

Thirteen main vegetation communities or ‘types’ were identified within the Hinewai Reserve study site (Fig 7.1). The following is a brief summary of the dominant species present in each vegetation type:

Beech: Red beech is the dominant canopy species in this community. Hall’s totara and small-leaved *Coprosma* spp. are common understory species but there are few other species in the understory except along streams where species such as pate, five-finger, fuchsia and mahoe flourish.

Coastal scrub: Present in and around the coastal gullies, this vegetation type is dominated by rohutu and small leaved *Coprosma* spp. which are interspersed with kanuka scrub.

Gorse/Broom: The last areas of pasture to be overtaken by thick gorse and broom scrub. In places kanuka has rapidly established and mahoe and fuchsia can also be found among young stands of gorse and broom.

Emerging natives: Saplings of shade tolerant species such as mahoe, fuchsia, five-finger, pate, *Coprosma* spp., lemonwood and wineberry that have established under canopies of gorse and broom (now >10 years old); many now overtop the gorse.

Exotic forestry: Two blocks of pine (*Pinus radiata*) and macrocarpa (*Cupressus macrocarpa*) have been planted in lower Otanerito Valley. Eucalypt (*Eucalyptus leucoxylon*) and wattle (*Acacia* spp.) has been planted adjacent to the south-east block.

Grazed pasture: Farmland, predominantly pasture with a few macrocarpa and eucalypt trees scattered around the farm.

Kanuka scrub: Young stands of dense kanuka that do not yet have a well-developed understory.

Mixed second growth: Young mixed broadleaf forest that has regenerated in gullies and under aging kanuka stands. This is the most diverse vegetation type in the study site, the main species are: *Coprosma spp.* mahoe, lacebark, fuchsia, pate, wineberry, kaikomako, kowhai, kanuka, putaputaweta (*Carpodetus serratus*), *Pittosporum spp.*, and *Pseudopanax spp.*. At higher altitude (>300 m) horopito is common, closer to sea level pigeonwood, ngaio, kawakawa and rohotu are common. Pohuehue, bush lawyer (*Rubus cissoides*) and supplejack are common climbers. In a few places old growth remnants containing kahikatea, matai and totara can also be found.

Regenerating forest in gullies outside of Hinewai Reserve is eaten out by stock. It has a similar but more limited composition because the understory lacks palatable species.

Ngaio: Isolated stands of ngaio grow close to the beach and have been planted in and around the houses near the beach.

Poroporo: Poroporo is most common in grassy areas close to Otanerito Homestead. Kanuka and a few kowhai trees also occur here.

Residential: There are three residential gardens in the study site. All three have a mix of native and introduced tree species. Two gardens include small orchards. One property has a stand of tree lucerne.

Ribbonwood/Horopito: A small stand of second growth forest dominated by ribbonwood and kowhai grows near Purple Peak Saddle. Horopito is the main sub-canopy species but mahoe, fuchsia and broadleaf are also common. Young Hall's totara can be found alongside horopito in more open areas.

Willow mixed: This is a mixed community growing along Narbey Stream and is dominated by willow, kanuka and kowhai. There is also a stand of walnut trees and a few eucalypt trees.

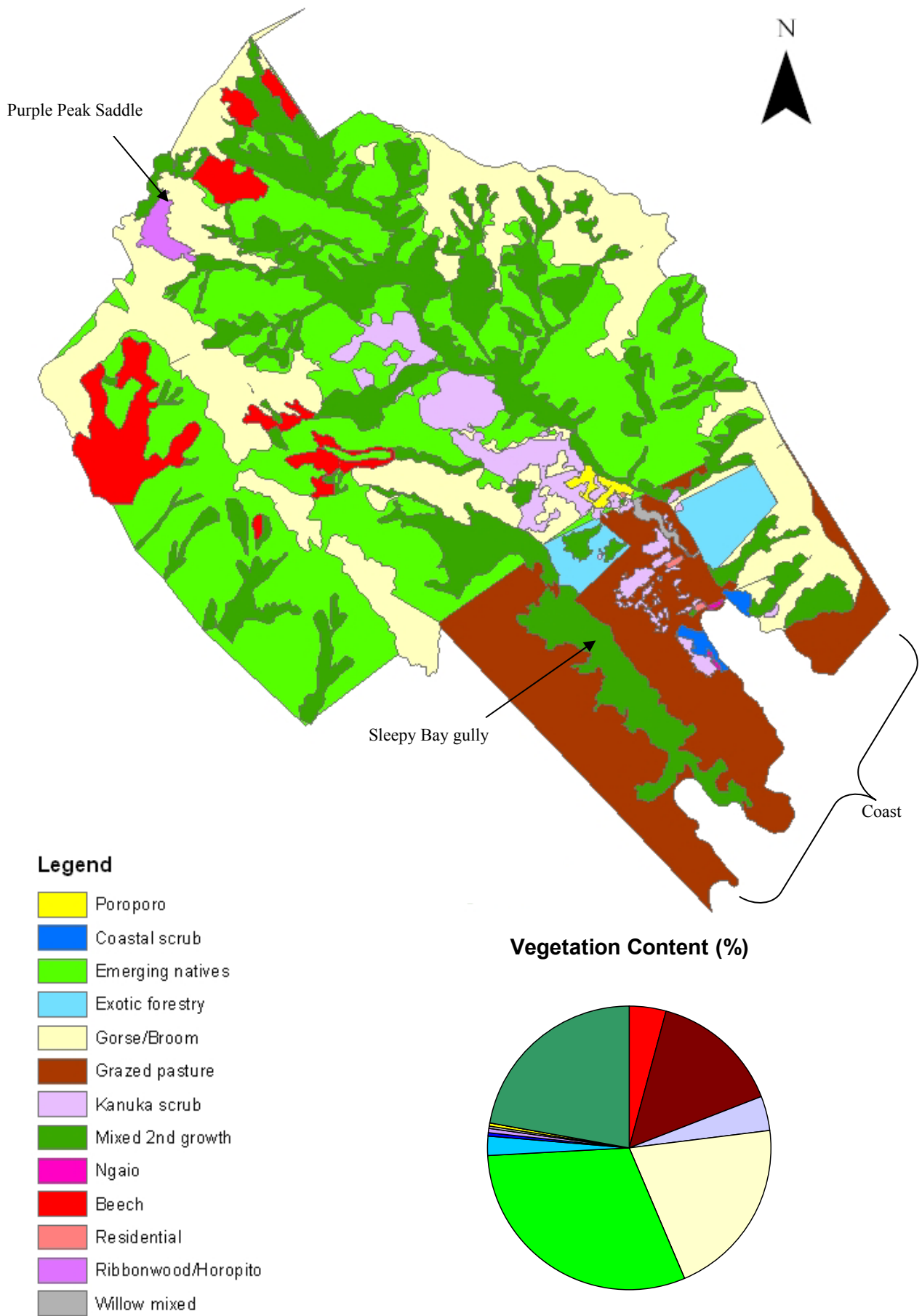


Figure 7.1. Vegetation map of the Hinewai Reserve study site and the proportion of each vegetation type in the reserve.

Table 7.1. Percent of each vegetation type within annual and seasonal home ranges (availability) and the percent of locations for each kereru in each vegetation type (use). Due to slight inaccuracies of the vegetation map percentages do not add to 100 (see 7.2.2).

Availability kereru #	Annual home range											Fruit -eaten season											No-fruit -eaten season											
	40	42	44	46	48	50	56	58	62	64		40	42	44	46	48	50	56	58	60	62	64	68	40	42	44	46	48	50	56	58	62	64	
Beech						10	11										4												21	24				
Gorse/Broom	34	27	8	30	5	49	5	35	17	27	29	20	6	6	7	21	3	20	18	20	20	15	32	24	3	31	5	50	7	50	21	8		
Exotic forestry		3			5				18	16		1	4		1					21	37	3		4			11						1	
Grazed pasture		29	37	2	44				10	25		15			31				2	9	10	24		36	29	4	46						45	
Native scrub	41	16	16	25	17			14	13	8	11	15	11	28	18			16	12	13	1	24	36	11	28	19	15			9		4		
Mixed 2nd growth	25	28	20	14	15	33	47	36	44	16	47	20	14	41	31	45	34	43	35	39	30	16	33	24	26	18	9	14	14	19	80	15		
Ngaio		1	1		1							2	1		1																			
Poroporo		2	16	31	7			18		4	15		11	32	12			25	28		5	18		1		28				24		7		
Residential Ribbonwood/ Horopito		2	4	1	2							1	4						1	7		1		4	15	2	3							
Willow mixed		4				10	39									36	60							8				16	57					
					8					8			1		1							6				1	13						23	

Use																																			
Beech						14	13										8											2			24	18			
Gorse/Broom	29	10	2	23	5	44	13	21	6	6	30	1	3	5	5	18	7	9			4	17	29	13	2	35	5	58	18	34	13	7			
Exotic forestry		4	1		12					5		3			2						7	5		6	1		18							3	
Grazed pasture		10	13		14				2	15		22	18		12				7	4	9	23		6	8		16							22	
Native scrub	31	12	9	9	10			10	1	1	14	16	10	15	12			11	2	1	2	18	45	7	8	6	8			7					
Mixed 2nd growth	37	44	30	54	25	24	23	55	86	47	49	53	50	65	52	49	39	52	64	86	54	24	27	39	13	47	7	9	11	57	86	39			
Ngaio		1	1		2							3	2		5																				
Poroporo		3	2	2	8	3		14	1	15	7	3	4	13	7			26	27	1	22	2		2		3				1		10			
Residential Ribbonwood/ Horopito		9	42	5	7			1		1			12	2	2			2				5		16	67	8	10							2	
Willow mixed		6				19	51									33	46			3				9				10	54						
					1	23				9					2							7				2	37							17	

NB. # 60 and 68 died in July therefore are not included in the annual results or 'no-fruit' season

7.3.2 Availability and use of vegetation types

All kereru had mixed second growth forest and gorse/broom available in their home ranges (Table 7.1). The two kereru at Purple Peak Saddle (#50 & 56) and # 40 had the most limited vegetation composition (four and three vegetation types respectively) in their home ranges. Kereru # 62 only had two vegetation types available in its home range when no fruit was eaten. For some kereru, vegetation types that were not available in their home range were used when kereru made excursions outside of their normal range of activity (these were classed as outlying fixes so were not included in calculation of home ranges). These vegetation types have high selection values in Table 7.2.

Vegetation communities containing large amounts of fruiting species such as poroporo, ngaio, and mixed second growth forest were used more when fruit was eaten compared to when no fruit was eaten (Table 7.1). Vegetation communities with large amounts of broom, tree lucerne and willow such as gorse/broom, residential and willow mixed were preferentially used by most kereru when no fruit was eaten (Table 7.1).

7.3.3 Selection of vegetation types by tagged kereru

Grazed pasture, native scrub, gorse/broom and exotic forestry were avoided by the highest proportion of kereru over the study period (Table 7.2; Fig 7.2). Willow mixed, poroporo, residential and mixed second were preferred by the highest proportion of kereru (Table 7.2; Fig 7.2).

Residential, ngaio and mixed second growth forest were preferred by the highest proportion of kereru when fruit was eaten (Table 7.2; Fig 7.2). Kereru # 50 and 56 did not use ribbonwood/horopito in the proportion to which it was available to them, but # 62 moved out of its normal range to use this vegetation type (Table 7.2). Exotic forestry and grazed pasture were avoided by a higher proportion of kereru compared with other vegetation types when fruit was eaten (Fig 7.2).

Beech, gorse/broom, exotic forestry, residential and willow mixed were preferred by a higher proportion of kereru when no fruit was eaten compared with the previous season (Fig 7.2). The proportion of kereru who preferred mixed second growth forest fell compared to the previous season and the proportion of kereru avoiding grazed pasture, poroporo and native scrub increased (Fig 7.2).

Table 7.2. Selection of vegetation types by each kereru annually and during each season. Jacob's index values range between -1 and +1. Values >0 indicate preference and values <0 indicate avoidance. Data for kereru #60 and 68 was only available for the fruit-eaten season. (-) indicates the vegetation type was absent from the home range.

■ Clear avoidance of a vegetation type ■ Clear preference for a vegetation type

Annual

Kereru	Vegetation Type										
	Ngaio	Beech	Grazed pasture	Native scrub	Gorse/Broom	Exotic forestry	Ribbon/Horopito	Willow mixed	Poroporo	Resident	Mixed 2nd growth
40	-	-	-	-0.2	-0.1	-	-	-	1.0	-	0.3
42	-0.1	-	-0.6	-0.2	-0.5	0.2	0.2	-	-0.1	0.6	0.3
44	-0.1	-	-0.6	-0.3	-0.6	1.0	-	-	-0.8	0.9	0.3
46	-	-	-1.0	-0.5	-0.2	-	-	0.7	-0.7	0.7	0.8
48	0.4	-	-0.7	-0.3	0.0	0.4	-	0.6	-0.4	0.7	0.3
50	-	0.2	-	-	-0.1	-	0.4	-	-	-	-0.2
56	-	0.1	-	-	0.5	-	0.2	-	-	-	-0.5
58	-	-	-	-0.2	-0.4	-	-	-	-0.2	0.3	0.4
62	-	-	-0.7	-0.9	-0.5	-1.0	-	-	0.9	-	0.8
64	-	-	-0.3	-0.8	-0.7	-0.5	-	0.1	0.6	0.3	0.7

Fruit-eaten season

Kereru	Vegetation Type										
	Ngaio	Beech	Grazed pasture	Native scrub	Gorse Broom	Exotic forestry	Ribbon/Horopito	Willow mixed	Poroporo	Resident	Mixed 2nd growth
40	-	-	-	0.1	0.0	-	-	-	-0.4	-	0.0
42	0.2	-	0.2	0.1	-0.9	0.7	-	-	1.0	-1.0	0.6
44	0.5	-	-0.7	-0.1	-0.4	-1.0	-	-1.0	-0.5	0.6	0.7
46	-	-	-	-0.4	-0.1	-1.0	-	-	-0.5	1.0	0.5
48	0.6	-	-0.5	-0.2	-0.2	0.6	-	0.3	-0.3	0.9	0.4
50	-	-	-	-	-0.1	-	-0.1	-	-	-	0.1
56	-	0.3	-	-	0.4	-	-0.3	-	-	-	0.1
58	-	-	-1.0	-0.2	-0.4	-	-	-	0.0	0.5	0.2
60	-	-	0.6	-0.8	-1.0	-	-	-	0.0	-1.0	0.5
62	-	-	-0.4	-0.8	-1.0	-1.0	1.0	-	0.9	-	0.8
64	-	-	-0.1	0.1	-0.7	-0.8	-	-	0.7	-	0.5
68	-	-	0.0	-0.2	0.1	0.3	-	0.1	-0.8	0.7	0.3

Table 7.2 continued...

No-fruit-eaten season

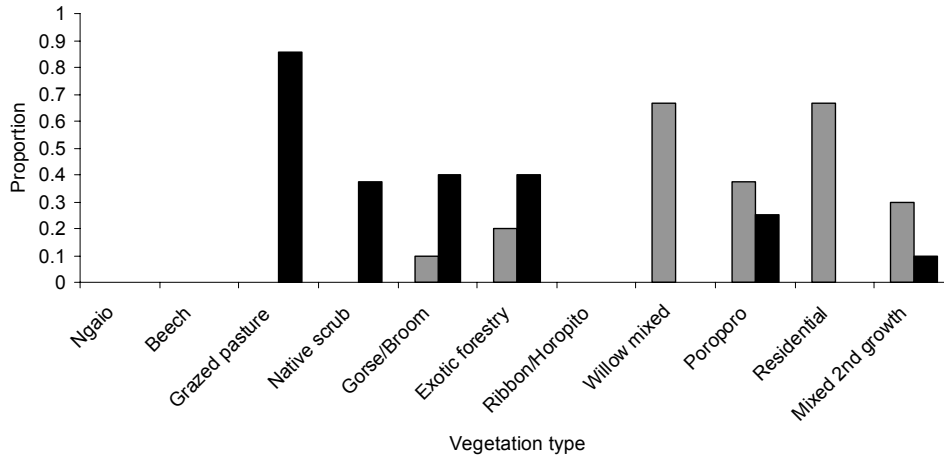
Kereru	Vegetation Type										
	Ngaio	Beech	Grazed pasture	Native scrub	Gorse/Broom	Exotic forestry	Ribbon/Horopito	Willow mixed	Poroporo	Resident	Mixed 2nd growth
40	-	-	-	0.2	-0.1	-	-	-	-	-	-0.1
42	-	1.0	-0.8	-0.3	-0.4	0.3	0.1	-	0.4	0.6	0.3
44	-	-	-0.6	-0.6	-0.1	0.9	-	-	-	0.8	-0.4
46	-	-	-1.0	-0.6	0.1	-	-	0.5	-0.8	0.7	0.6
48	-	-	-0.6	-0.3	-0.1	0.3	-	0.6	-	0.6	-0.1
50	-	0.1	-	-	0.1	-	-0.3	-	-	-	-0.3
56	-	-0.2	-	-	0.5	-	-0.1	-	-	-	-0.1
58	-	-	-	-0.1	-0.3	-	-	-	-0.9	-	0.7
62	-	-	-	-	-0.3	-	-	-	-	-	0.2
64	-	-	-0.5	-1.0	-0.1	0.6	-	-0.2	0.2	1.0	0.6

7.3.3.1 Selection of vegetation assemblages

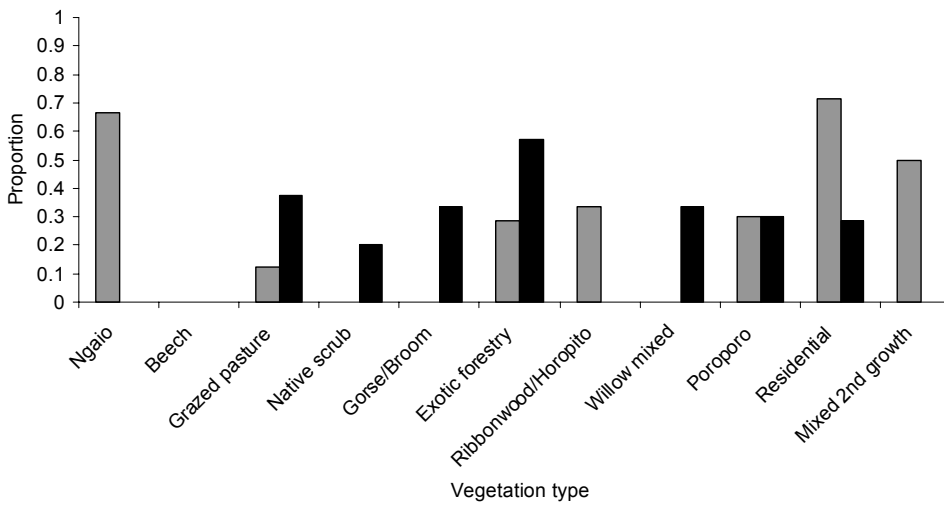
Vegetation communities dominated by introduced species were used proportionally less than they were available over the study period and also when fruit was eaten (Fig 7.3). Native vegetation communities were used proportionally more than they were available during these times. When no fruit was eaten native vegetation communities were used proportionally less than they were available, exotic vegetation communities were used equal to their availability.

Forest communities were used proportionally more than they were available over the study period and during both seasons (Fig 7.3). Selection for forest communities was greater when fruit was eaten than when no fruit was eaten. Non-forest communities were used proportionally less than they were available over the study period and during both seasons.

Annual



Fruit-eaten season



No-fruit-eaten season

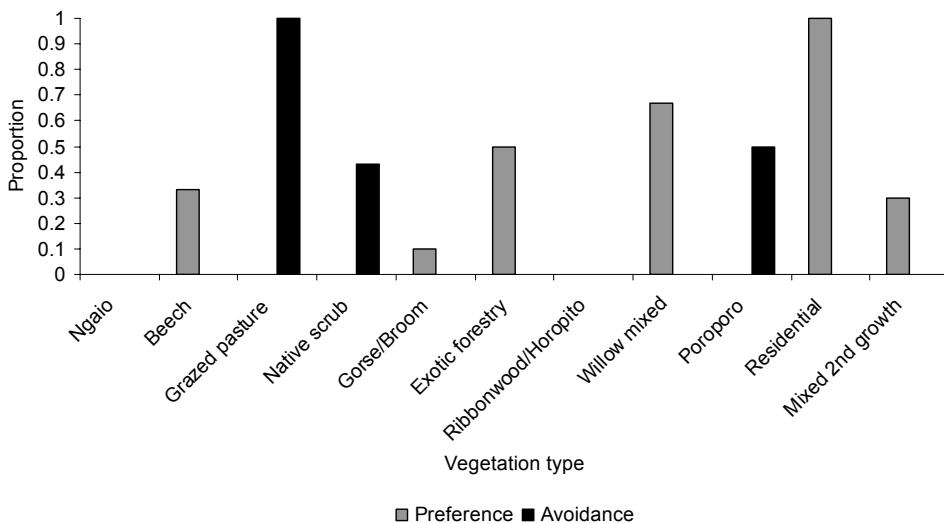
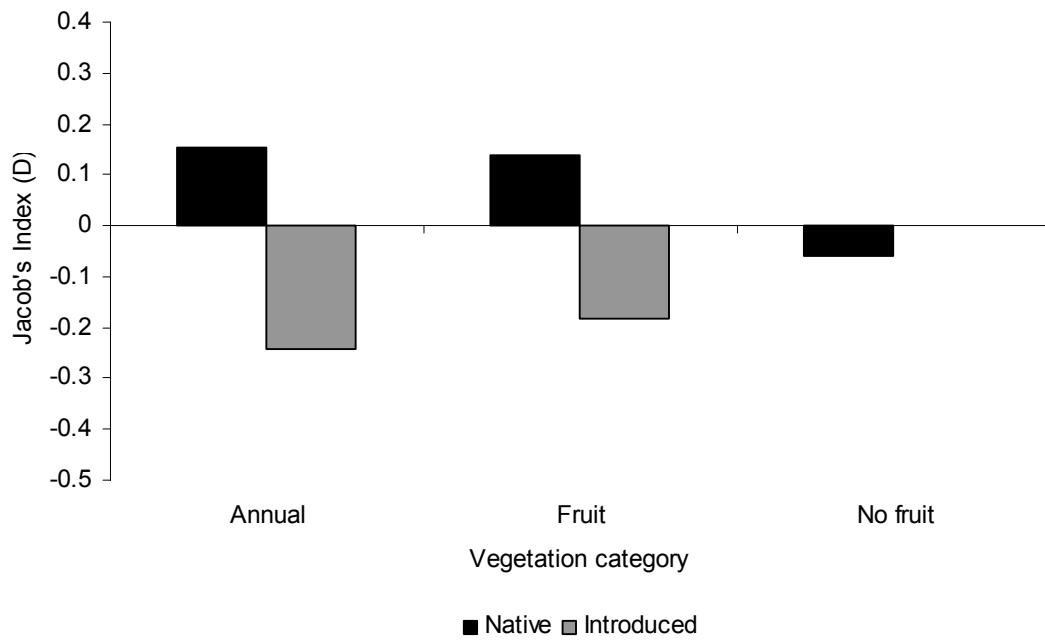


Figure 7.2. The proportion of kereru that preferred and avoided each vegetation type annually and each season. Blank spaces indicate that no kereru preferred or avoided the vegetation type in that time.

Native vs. non-native



Forest vs. non-forest

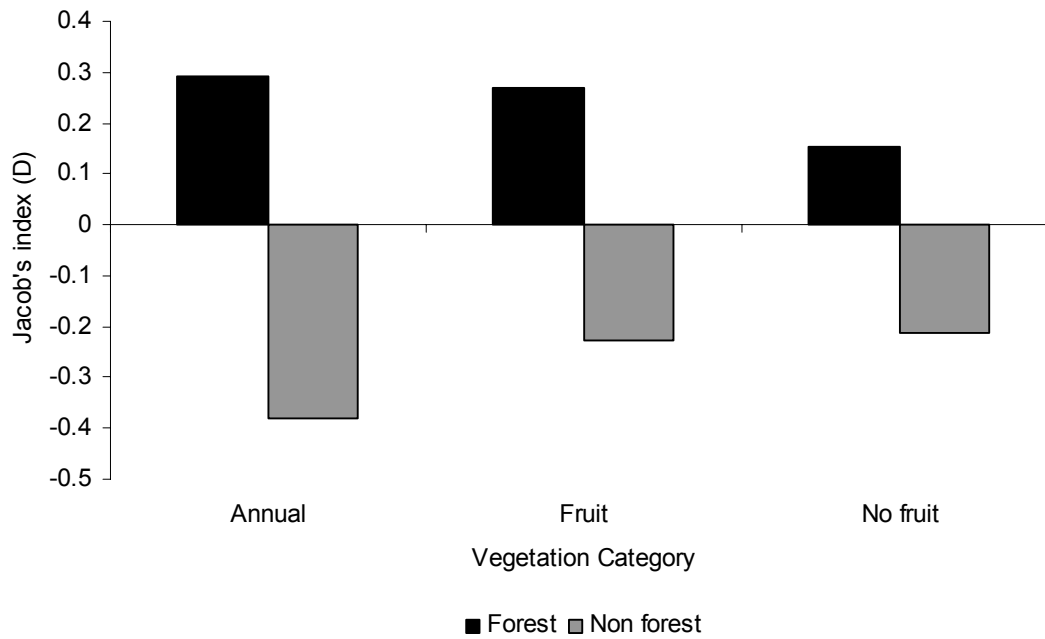


Figure 7.3. Kereru selection of native vs. non-native and forest vs. non-forest vegetation groups annually and seasonally.

7.3.4 Plant species used for non-feeding activities

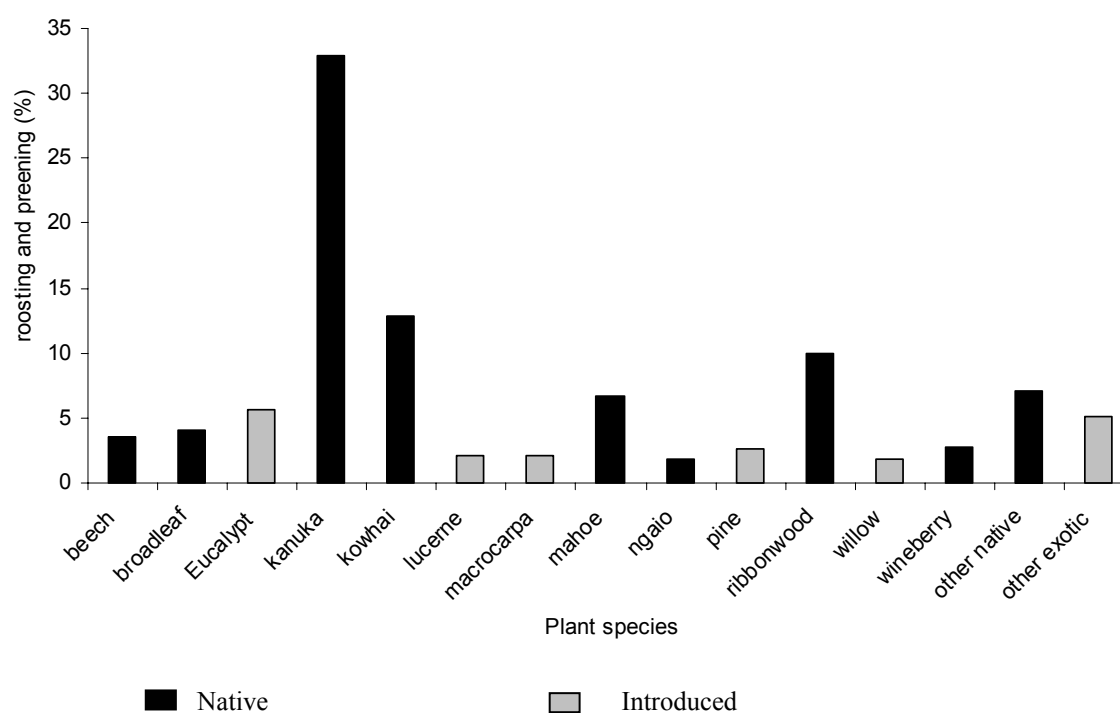


Figure 7.4. Plant species used by kereru for resting and preening throughout the study period at the Hinewai Reserve study site. Frequency of use is expressed as a percentage. Species used <2% of the time were grouped together under ‘other’ on the basis of whether they were native or introduced.

A total of 31 species or sites were used for non-feeding activities. Twenty-one of these species were native and 10 were introduced. Species and sites in the ‘other native’ and ‘other introduced’ categories were:

Other native

cabbage tree
 dead trees
 fuchsia
 kaikomako
 kahikatea
 kawakawa
 karamu
 pigeonwood
Pittosporum spp.
 putaputaweta
 northern rata (*Metrosideros robusta*)
 rewarewa (*Knightia excelsa*)
 rohutu

Other introduced

elm (*Ulmus* spp.)
 powerline
 silverbirch
 walnut (*Juglans* spp.)
 wattle (*Acacia* spp.)

The three tree species used most often for non-feeding activities were kanuka, kowhai and ribbonwood (Fig 7.4). Kanuka was used twice as often as kowhai, the next preferred species. All other species comprised of less than 10% of observations (Fig 7.4) There was no significant difference in the proportions of native and introduced species used for non-feeding activities (t-test, $P=0.1$).

Tagged kereru nested in five plant species. Kanuka with eight nests was used considerably more than other species which had one nest each. Other species were narrow-leaved lacebark (*Hoheria augustifolia*), northern rata, rewarewa and rohutu. Nine nests were in mixed second growth forest, two nests were in kanuka scrub and the northern rata was a garden specimen.

7.4 Discussion

7.4.1 Selection of vegetation types

Not surprisingly the two major vegetation types in the study site, mixed second growth forest and gorse/broom were included in the home ranges of all tagged kereru throughout the study period. Use of vegetation types varied between the kereru in different areas of the study site and also between individual kereru that resided mainly in the lower valley. The lower part of Otanerito valley is significantly more modified than the upper half of Otanerito Valley and contains a variety of native and introduced habitat types. As a result kereru who were residents of the lower valley (# 40, 42, 44, 46, 48, 58, 60, 64, and 68) had a wider range of vegetation communities to select from in a small area compared to kereru at Purple Peak Saddle (# 50 and 56) and in Sleepy Bay (# 62). This was evident in the number of vegetation types available in home ranges of these kereru.

While there were kereru living in mid-altitude (200-500 m) areas of Hinewai Reserve, which are more forested, none of these kereru were included in the tagged sample. Therefore habitat selection results in this chapter are not representative of all kereru in the study site. Kereru at mid-altitudes of the reserve would have mainly mixed second growth, emerging natives, gorse/broom, kanuka and possibly beech available to them (Fig 7.1). Mixed second growth would probably be used more by these kereru than the tagged kereru in this study. It is also likely that many of these kereru would travel to ribbonwood/horopito or poroporo to feed during peak fruiting.

Mixed second growth forest was preferred by more kereru when fruit was eaten because it had a large number of fruiting species available during that time. When fruit was eaten only one garden was used frequently because it had a large number of ngaio trees in the garden. A different garden was used heavily when no fruit was eaten because tree lucerne was abundant. As so many kereru were observed feeding on poroporo during peak fruiting it was expected that it would be preferred by more tagged kereru than was observed. A possible explanation for this is that kereru only fed on poroporo for short periods of time and then flew to nearby forest to rest. There were few suitable resting trees in this vegetation type, which is highlighted by the rare use of this vegetation type when no fruit was eaten.

Grazed pasture, native scrub and exotic forestry contained few or no food species. They were used by kereru while resting after feeding or in transit from food to rest sites. Exotic forestry was used more when no fruit was eaten because both blocks were located close to patches of broom and willow. Grazed pasture was used more when fruit was eaten because ngaio and rohutu fruited near the coast and kereru usually moved out of foraging areas to nearby macrocarpa or eucalypt trees located on farmland. Kereru in this study were not observed feeding on pasture species e.g. clover (*Trifolium repens*), as has been observed with kereru on Kapiti Island (I. Castro, *pers. comm.*) and parea (Powlesland *et al.*, 1997). Unlike the Hinewai Reserve site, Kapiti Island is predator free and Chatham Island is free of mustelids, although cats are present (M. Bell, *pers. comm.*). It may be that kereru on Banks Peninsula have already adapted their behaviour in response to predation pressure. While they fed in low bushes such as broom and poroporo they were never observed resting in these species. This may be why the results showed few kereru with a preference for gorse/broom.

Ngaio was not used when fruit was unavailable so was probably not a preferred resting habitat. Despite ngaio being common on the coast in Otanerito Bay, kereru did not rest in these trees when no fruit was available but frequently rested in macrocarper trees just meters away. Ribbonwood/horopito was only preferred when fruit was eaten even though ribbonwood trees were used for non-feeding activities during the whole year. The only kereru that preferred this vegetation type was # 62 who travelled outside of its normal range to feed on horopito fruit. Other kereru travelled long distances to feed on horopito indicating that ribbonwood/horopito is highly preferred by kereru who may lack similar food sources in their normal range at this time of the year. It was presumed beech forest was used by kereru for roosting at night as many kereru were seen there close to dawn and dusk. Beech forest may have been selected

because it was close to feeding areas. Kereru sometimes rested there during the day but few fixes were obtained (normally only first thing in the morning).

Selection of vegetation groups followed the same trend as preference of individual vegetation types. Communities dominated by native species were used proportionally more often when fruit was eaten because a) fruit was abundant in most native habitats when fruit was eaten and b) there was virtually no fruit of exotic species available to kereru. Use of introduced vegetation types increased when kereru fed on broom, willow and tree lucerne. More noticeable selection was observed when vegetation types were grouped into forest habitat and non-forest habitats. Kereru spent most of their time resting in trees and these were often in mixed second or exotic forest. Some non-forest habitats contained important food species and kanuka scrub was used for nesting but otherwise kereru spent little time in non-forest habitat.

Schotborgh (2005) did not calculate preference of habitat types by kereru in the Lyttelton Harbour area, a highly modified urban-rural landscape on Banks Peninsula that includes Orton Bradley Park and Church Bay. However, she did determine relative use of habitats by all kereru over the entire study period. Although direct comparison is difficult there was one main difference and several similarities with the results of this study. The most fixes on tagged kereru in Orton Bradley Park and Church Bay were collected in residential gardens (34%) (Schotborgh, 2005). In the present study the highest percentage (43%) of location fixes were collected in mixed second growth forest. The vegetation composition of the Hinewai Reserve study site was quite different compared with the Lyttelton Harbour study site. This is reflected by the dissimilarity of the major vegetation type used by kereru at each study site. In both studies, habitats dominated by native and introduced species were used. The extent to which habitats were used by kereru was seasonal. Kanuka was chosen the most for nesting. Like some of the kereru in the present study, six kereru from Orton Bradley Park travelled to high altitude reserves in autumn presumably attracted to autumn fruiting species such as horopito.

7.4.2 Selection of species for non-feeding activities

A greater number of native plant species were used for non-feeding activities compared to exotic species. The four most popular species for non-feeding activities were all native species. Kereru usually spent resting and preening time in vegetation offering good overhead cover (pers. obs.). Mixed second growth forest is ideal because the canopy is dense and very few trees are deciduous. Not surprisingly the four species used most often for non-feeding activities were very common in mixed second growth forest; kanuka is also common in most

parts of the study site. Kanuka was by far the most often used species although kanuka in forest was used more than kanuka scrub. It is likely that kanuka met several criteria such as good overhead cover, proximity to food sources and branches that were a good diameter for perching.

Kanuka was also favoured as a nesting tree with 67% of nests being built in kanuka. Two other nests were built in very bushy species (rata and rohutu) and the nest in the lacebark tree was built in the crown of a young tree with dense leaves. Clearly overhead cover is important to kereru when selecting nesting sites. Hill (2003) suggests that this is to prevent predation by raptor species. Kahu (*Circus approximans*) are a potential threat to kereru chicks on Banks Peninsula and New Zealand falcon (*Falco novaeseelandiae*) were once common there.

Eucalypt and macrocarpa were used more than would be expected considering they were not common in the study site. Large groups of kereru often congregated in these trees. The attraction of these trees was possibly their height and the fact that they were close to foraging areas that weren't suitable for resting. It would also have been an opportunity for social interaction with other kereru, and may have been especially important in the build up to the breeding season.

In their study on the Chatham Island pigeon (parea), Pearson & Climo (1991) found that hoho (*Pseudopanax chathamicus*) and mahoe, species used frequently for foraging, were most preferred for all activities. Some food species used by kereru in this study were also used for non-feeding activities. Trees that were commonly used for both feeding and resting were kowhai, mahoe, willow and tree lucerne. All these trees provided overhead cover and were in the 4-12 m height range. Tree lucerne trees that were less than four metres in height, or off the ground (i.e. growing on the side of a bank), were seldom used for resting. Species in scrub habitats or low to the ground (i.e. poroporo, coastal scrub and broom) were never used for resting in. The avoidance of low species for resting could well be a response to predation pressure. Ridley (1998) also found that kowhai was preferred by kereru for all activities. Like kereru in this study, the majority of kereru in Waihi Bush, South Canterbury, were observed 4 to 12 m off the ground (Ridley, 1998). Because Waihi Bush had a very different vegetation composition compared to the Hinewai Reserve study site, detailed comparison was not possible.

7.4.3 Conclusions

Use and preference for many vegetation types was seasonal; this was probably because of the availability of food species included in or close to these vegetation types. Overall, native vegetation communities were used more than communities dominated by introduced species. This is almost certainly because native habitats were used frequently for both feeding and non-feeding activities. Use of communities dominated by introduced species increased when kereru switched from feeding on native species to introduced species. Forest habitats were preferred over non-forest habitats throughout the year because non-forest habitats did not have many trees suitable for non-feeding activities.

It is presumed that kereru at mid-altitude in Hinewai Reserve would use mixed second growth forest more than tagged kereru did. However habitats containing introduced species such as willow and tree lucerne may have been preferred by these kereru at certain times of the year had they been available.

Planning of habitat enhancement aimed at increasing kereru numbers will have to take into account the need for suitable habitat for non-feeding activities. When planting native species some forest habitat should be planned. Figure 7.4 summarises the plant species most frequently used for non-feeding activities. These species are most recommended for planting or retaining in existing habitat on Banks Peninsula; many also double as food species. Kanuka is highly recommended. It is fast growing, makes a good nurse crop and would provide kereru with favoured nesting and resting sites within regenerating forest. Species that are no longer as common on Banks Peninsula but which are also recommended for planting are matai, totara and kahikatea.

Chapter 8

General discussion

8.1 How did this study contribute to the Kaupapa Kereru Programme?

The main goal of the Kaupapa Kereru Programme (KKP) is to increase the numbers and range of kereru on Banks Peninsula. To make this goal a reality the strategic plan of KKP for the next 5-10 years includes proactive management in the form of predator control and habitat restoration, further research and monitoring of managed sites, community education and involvement by making information available to people wanting to enhance their properties for kereru. At the end of five years it is hoped that the population and range of kereru on Banks Peninsula will be noticeably greater.

Before management could take place, it was first necessary to study kereru ecology at study sites that were representative of Banks Peninsula's modified and diverse landscape. This study was an integral part of the KKP because it complemented previous studies conducted in Lyttelton Harbour (Schotborgh, 2005), a heavily modified urban-rural landscape, by investigating kereru ecology in an area of regenerating native forest. It also helped raise awareness in the Akaroa community for the plight of the kereru and reasons why research and management are necessary for enhancement of the kereru population.

8.2 How did this study contribute to knowledge of kereru in the wider context?

Until the 1970's, little was known about kereru ecology and published material was mostly based on anecdotal evidence from casual sightings, who provide a limited description of kereru feeding behaviour, for example Taylor (1950). Early research focused on feeding ecology and confirmed previous reports that kereru were versatile and generalist feeders (Dunn, 1981; Gibb, 1970; McEwan, 1978). Use of radio-tracking for studying kereru began in the mid to late 1980's and provided the first reliable data on their movements and habitat use of kereru in forest habitats (Clout *et al.*, 1986; Clout *et al.*, 1991). These studies linked the availability of food with seasonal movements. Subsequent studies investigated feeding behaviour, seed dispersal, home range size, movements and breeding biology of kereru (Clout *et al.*, 1995; Pierce & Graham, 1995; Bell, 1996; Hill, 2003; Prendergast, 2006; Ridley, 1998; Schotborgh, 2005). These studies were conducted in continuous tracts of native forest, old growth forest

remnants and urban-rural landscapes. The Department of Conservation is currently studying kereru ecology in the urban centres of Invercargill and New Plymouth (R. Powlesland, *pers. comm.*).

My study has added to existing knowledge of kereru by investigating kereru ecology in a very different region of New Zealand. The Banks Peninsula landscape is highly modified with large rural areas, small urban areas, small fragments of regenerating native forest and very little old-growth forest. Habitat in the Hinewai Reserve study site differed from habitat in previous study areas because it contained a large fragment (1050 ha) of regenerating native forest. Forest was in the early stages of succession and was dominated by small-fruited (<12 mm diameter) native species. Fruit was unavailable for roughly five months of the year. The only other detailed studies carried out in habitat with similar characteristics have been Clout *et al.* (1986) and to a lesser extent Schotborgh (2005), where the study area contained a much smaller proportion of native vegetation. Information from this study can be used to guide further research of kereru ecology in other rural areas containing fragments of regenerating native forest.

Estimates of annual and seasonal home ranges were determined with greater accuracy in this study than in most other previous studies. This was due to the availability of improved home range estimators and software for analysing tracking data. By locating each tagged kereru daily, it was possible to collect detailed information on daily movements, feeding and habitat preferences of individual kereru. With the exception of Schotborgh (2005) other studies of radio tagged kereru have not located individuals on a day-to-day basis.

Results from this study, along with other studies, will be reviewed by the Department of Conservation and may help to develop improved monitoring and management programmes which will be implemented nationwide (Mander *et al.*, 1998).

8.3 Quality of the Hinewai Reserve, Akaroa and Lyttelton Harbour study sites as kereru habitat

For many animals, home range size decreases with increasing habitat quality (Walsh, 2002). It was assumed that the Hinewai Reserve study site would have better quality habitat than the Lyttelton Harbour because a large amount of native forest was available. It was expected that kereru would move over smaller distances to forage, and therefore have smaller home ranges,

than Lyttelton Harbour kereru. When comparing study sites it was clear that home range size alone was not an accurate measure of habitat quality, as it did not take into account the density of kereru that could be supported by each study site. 'Quality kereru habitat' was hard to define as preferred vegetation types varied between individuals and study sites. Based on the results of both studies, high quality kereru habitat contained a diverse range of preferred fruiting species and also deciduous and legume species which provided sufficient protein to allow early breeding to take place prior to the fruiting season.

Home range sizes observed in this study were larger than observed in Lyttelton Harbour (Schotborgh, 2005) perhaps because more preferred food and nest resources were available over a larger area. Quality kereru habitat in the Lyttelton Harbour study sites was either highly fragmented and interspersed by large areas of unsuitable habitat such as pasture (Orton Bradley Park) or very localised (Church Bay) (Schotborgh, 2005). Fragments of quality habitat were larger and more uniformly spread in the Akaroa and Hinewai Reserve study sites (pers. obs.). As a result the Akaroa and Hinewai Reserve study sites would almost certainly support a larger number of kereru per hectare than the Lyttelton Harbour study site. Data on the density of kereru at both study sites is not available to support this assumption. However, observations were made of flocks of up to 100 kereru in Otanerito valley whereas Schotborgh (2005) estimated that a maximum of 34 kereru were present in either of the Lyttelton Harbour study sites during the study period.

Otanerito Valley, a large part of the Hinewai Reserve study site, appeared to provide the most resources within a relatively small area. Otanerito Valley contained a greater quantity of native fruiting species than Akaroa or Lyttelton Harbour, and an abundance of native and introduced legumes meant there was ample food when fruit is unavailable. Kereru in Sleepy Bay, Akaroa and Lyttelton Harbour left their study areas to forage when food was scarce in their normal ranges. No tagged kereru left Otanerito Valley during the study period indicating all the required resources were contained within the valley.

8.4 Seed dispersal by kereru in regenerating forest habitat

It was predicted that an increase in the number of kereru on Banks Peninsula would assist regeneration of native forest. In Ahuriri Summit Bush, Banks Peninsula, 86% of plant species were found to be fleshy-fruited and all of these were dispersed by birds (Burrows, 1994). Banks Peninsula once also had other endemic birds that ate fruit of native species. Extinct or

locally extinct birds that are likely to have dispersed the seeds of fleshy fruits are: kokako, saddleback (*Philesturnus carunculatus*), piopio, finsch's duck, New Zealand raven (*Corvus* sp.) and several species of moa (*Anomalopteryx* and *Megalapteryx* spp.) (Wilson, 2004). Rare sightings of tui are made but there is no longer an established population on Banks Peninsula. The only endemic birds remaining on Banks Peninsula, which disperse the seeds of fleshy fruits, are kereru, bellbird and possibly brown creeper. Because kereru is the only bird capable of dispersing seeds of all sizes it was assumed that increasing kereru numbers and range would play a major role in the regeneration of native forest (K-J. Wilson, *pers. comm.*).

In Hinewai Reserve gorse and broom have established on pasture and act as a nurse crop for seedlings of native species. The majority of emergent native species in gorse and broom scrub are small fruited (<10 mm diameter) species such as mahoe, wineberry, *Pseudopanax* spp, pate, fuchsia and *Coprosma* spp. Kereru were not observed resting in emergent natives growing in gorse and broom scrub and only fed on broom when no fruit was consumed. Therefore they are not the main dispersers of the seeds into regenerating scrub and are not essential for the initial stages of regeneration. This may explain why species such as pigeonwood which produce some seeds that are c. 10 mm in diameter (Burrows, 1994), are not establishing under gorse. Smaller birds such as silvereye, blackbirds, bellbirds and song thrush are more likely to be dispersers of small seeded species in gorse and broom.

The only large fruited (>12 mm diameter) species native to Banks Peninsula are miro, poroporo, passion flower (*Passiflora tetrandra*), and karaka (Burrows, 1994). Of these species only passion flower and poroporo are found in Hinewai Reserve. Tagged kereru ate poroporo but were not the sole disperser, as silvereye and other small birds also feed on poroporo which has numerous small seeds. If large seeded species such as miro and karaka were abundant on Banks Peninsula, seeds would be dispersed by kereru in areas of existing forest but not into regenerating scrub where gorse is the nurse species.

As the existing native flora of Banks Peninsula consists largely of species with fruit smaller than c. 10 mm in diameter (Burrows, 1994), introduced birds have joined with native birds in the role of seed dispersal. Williams and Karl (1996) investigated the relationship between fleshy-fruited native species and adventive weeds in the diet of birds near Nelson. The Nelson study sites were small forest fragments in the urban-rural landscape (Williams and Karl, 1996) and were fairly representative of the Banks Peninsula environment. Birds present were also representative of birds on Banks Peninsula. They found that introduced birds fed mostly on

introduced fruit and native birds fed mostly on native fruit. This would make introduced birds less efficient dispersers of native species in habitats such as Akaroa where a wide range of introduced species are available. As there is less than a handful of introduced fruit trees capable of dispersal by kereru in Hinewai Reserve, introduced bird species play a major role in forest regeneration.

8.5 Monitoring of kereru on Banks Peninsula

The nature of the landscape on Banks Peninsula poses a problem when choosing a method for monitoring population trends that can be used at all sites. Fragments of habitat suitable for kereru (native and introduced) are rarely big enough to accommodate the minimum number of count stations required for 5-minute counts - recommended by Mander *et al.* (1998) as the most suitable method for monitoring kereru. Five minute counts also rely on 'look up' methodology which can be very difficult in regenerating forest where the sub-canopy and canopy is usually dense. Further more, the forested terrain on Banks Peninsula tends to be steep and the vegetation difficult to walk through. Census counts can also be ruled out at many sites as the density of kereru is too high to identify individual birds with confidence.

I suggest using a method devised by Bibby *et al.* (1998) that is similar to a standard census count (which estimates the minimum number of birds in an area by counting individuals), but instead involves cue counting from vantage points (and does not require tracking of individual birds). As kereru usually fly above the canopy and are very conspicuous when flying, flight is the obvious choice of cue. The following method will only be useful for calculating population increase at the same site from count to count but not for comparing sites. This is because kereru at different sites may fly more often than kereru at other sites. Bias of this type can be minimised by adding a second component if site comparison were desired.

The cue count method works by calculating a relative index of abundance by recording the total number of flights in a known area and expressing this as the mean number of flights/hour/unit area. This is based on the assumption that the more birds there are in an area, the more flights will be recorded. An essential part of this method is that *all* flights made within the area are recorded; this is likely with kereru as they spend little time flying. The area of each monitored site could be calculated easily with Geographic Information System (GIS) software using GPS fixes and bearings taken at each fix. This method is simple and ideal for

valleys and therefore well suited for use on Banks Peninsula. See 8.5.1 for a full explanation on how this method works.

Cue counts would need to be done at the same time of year, and at the same time of day. The first four hours after dawn (for the full four hours) would be the most suitable time period as kereru are most active and nest change over times would be included. Late summer or early autumn would be the best time of year because kereru are more mobile when they are feeding on fruit. Possible increases/decreases in movement during mast fruiting years would have to be taken into account, perhaps by working out a confidence interval that would allow for this. For small habitat fragments few people would be required (I estimate that one person could easily monitor an area of 500 m² from a good vantage point). Larger habitat fragments could be split up into sections and each section done by a different person. Bias would be created if birds flew between sections, but as long as the section boundaries were the same every year, bias would be standardised and therefore would not affect monitoring of population increase. I recommend trialling this method on Banks Peninsula to determine whether it would be a useful tool for pre and post-management monitoring (i.e. before and after habitat restoration and/or control of introduced mammals).

8.5.1 Cue counting from vantage points (from *Bibby et al.*, 1998: 70-71).

In cases where birds are not extremely rare, it is often difficult to identify individual birds with confidence. However, watches can still yield population measures and these may be useful in very rugged terrain such as steep valleys (where look up techniques are difficult). The method can have one or two components:

- a) Within a known area, the number of flights made is recorded and expressed as mean number of flights per hour per unit area (a relative abundance index). The assumption is that the more birds there are, the more flights you will record. Remember, most birds tend to fly more early in the morning and in the evening than in the middle of the day. A serious limitation is that birds in one area may fly more than those in another. This could easily be habitat-dependant, with birds in poor habitats perhaps having to fly further.
- b) An extension of this method, and a possible way round the above problem, is to find out how much time an average bird spends in flight per hour. From your vantage point, locate a bird in flight and follow it until it perches. Then record the amount of time it spends

sitting/feeding. When it takes off again, time its flight. Obviously, you will need to do this many times.

So now you know (1) what fraction of its time the average bird spends in flight, and (2), how many flights are made (by an unknown number of birds) per hour within a known area. To work out your population estimate, divide (2) by (1). For example, an ‘average bird’ spends 1 minute out of each hour flying. You recorded ten minutes of flight by all birds in one hour. Your population estimate in the area is ten birds. The essential parts of this method are that you, (a) detect every flight made by all birds in the area (so several observers may be necessary), and (b) your data on how much a single bird flies is good enough. This form of censusing is cue counting and in this case, the cue is bird flight. The cue can also be birdcalls.

8.6 Key findings important for management

- A range of native species that fruit over summer, autumn and winter are available for planting on Banks Peninsula. Species from each group should be included in habitat restoration so that fruit is available for the longest time possible. Plants in full sun appeared to be more productive indicating that trees on forest margins and emergent trees could be more valuable to kereru than shaded trees.
- Native fruit was preferred by kereru when available (Fig 8.1). Fruit of introduced species is likely to be important to kereru when native fruit is unavailable (Fig 8.1). Larger-fruited species (>10 mm diameter) may be of more value to kereru than small-fruited species.
- A protein rich foliage diet clearly provides sufficient nutrition to trigger breeding and sustain breeding kereru. New leaves of broom appeared to be preferred over new leaves of kowhai and other native species. In Lyttelton Harbour, tree lucerne was heavily used during autumn, winter and spring (Schotborgh, 2005). A combination of legumes and deciduous species should be included in habitat restoration to provide food for kereru when fruit is unavailable (Fig 8.1). It is advisable to retain legumes or deciduous species indefinitely as these species provide valuable supplementary food.
- A diverse range of preferred species is required throughout the year to encourage kereru not to travel to seasonal home ranges elsewhere. Habitat quality can be

increased by making preferred fruiting species available for as much of the year as possible. Large fragments of native forest with a range of native and introduced plant species appeared to allow for a higher carrying capacity of kereru per unit area.

- Planned habitat restoration should take into account the need for suitable habitat for both feeding and non-feeding activities. Kanuka was used most frequently by kereru for resting and nesting. Kanuka is highly recommended for habitat enhancement as it is fast growing and an excellent nurse crop for other native species. Kanuka trees (usually >4 m in height) were preferred over kanuka scrub. Species used frequently for non-feeding activities in this study are shown in Table 8.1.
- Food is currently not a limiting factor for the survival of kereru on Banks Peninsula. The main factor limiting population growth in this study was failure of nests at the egg and chick stage (see Appendix 6). Adult mortality was relatively low; 13% of tagged kereru died. Adult mortality was high in Lyttelton Harbour (28%) but the fledge rate was higher than most other mainland sites (35%) (Schotborgh, 2005). Control of predators will almost certainly increase reproductive success of kereru and loss of breeding adults.
- As the population of kereru on Banks Peninsula increases due to predator control in existing kereru habitat, food could become a limiting factor. It is necessary to start habitat enhancement in areas both currently suitable and unsuitable for kereru so that vegetation is well established when kereru numbers and range expand.
- Migration and flocking behaviour of kereru at certain times of the year will need to be taken into consideration when designing monitoring methods for studies of population dynamics.

Fruit	Time of the year eaten by kereru											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cabbage tree	■	■	■	■								
<i>Corokia x</i>					■							
Crab apple *					■							
Five-finger	■											
Fuchsia	■	■										■
Holly *			■		■		■					
Horopito				■	■							
Karamu		■	■	■	■							
Kawakawa		■	■	■								
Kaikomako			■									
Kohuhu					■	■						
<i>Lophomyrtus x</i>					■							
Mahoe	■	■	■	■	■	■						
Ngaio	■	■	■	■	■							
Pate				■								
Phoenix palm *		■										
Pigeonwood	■		■									■
Plum *	■	■										■
Poroporo	■	■	■	■								
Rohutu				■	■	■						
Supplejack			■									
Wineberry	■											
Yew *		■	■	■	■							
Foliage & Flowers												
Deciduous												
Apple *									■			
Apricot *								■	■	■	■	■
Ash *				■								
Plum *									■	■	■	■
Poplar *				■						■	■	■
Ribbonwood						■	■					
Legumes												
Broom *					■	■	■	■	■	■	■	■
Kowhai	■											■
Laburnum *											■	■
Tree lucerne *	■				■	■	■	■	■	■	■	■
Evergreen												
Broadleaf									■			
Kohuhu									■			
Lacebark				■				■	■	■		
Mahoe	■						■	■	■	■		
Pohuehue			■					■	■		■	
Titoki									■			
Virgilia *	■							■	■	■	■	■

* Introduced species

Figure 8.1. Species eaten by kereru in this study and recommended for enhancement of habitat for kereru on Banks Peninsula. Scientific names are found in Appendix 4.

Table 8.1. Plant species most frequently used for non-feeding activities.

Native Species	Introduced Species
Kanuka	Eucalypt
Kowhai *	Pine
Ribbonwood *	Tree lucerne *
Mahoe *	Macrocarpa
Broadleaf *	Willow *
Beech	
Wineberry *	
Ngaio *	

* also food species

8.7 Management of kereru

The most common threats to kereru survival identified in previous studies and summarised in Mander *et al.* (1998) are predation by mammalian predators, loss and degradation of lowland forest (or the lack of suitable habitat containing native and/or introduced plant species), illegal hunting and collisions with windows and motor vehicles. Apart from illegal hunting, which is not known to occur on Banks Peninsula, the same limitations to population growth and range expansion of kereru have been identified by this study and studies in Lyttelton Harbour and Lyttelton Harbour (Schotborgh 2005 and Prendergast 2006).

8.7.1 Management recommendations

The following management options would be suitable for use on Banks Peninsula as well as on a national scale:

1. Predator control

It is essential that stoats, cats, rats (*Rattus spp.*) and possums be controlled to allow significant population growth of kereru (Clout *et al.*, 1995; Pierce & Graham, 1995; Powlesland *et al.*, 2003; Prendergast, 2006). Appendix 6 shows the fate of observed nests and discusses the possible causes of nest failure and adult mortality. It would be useful to get an idea of predators that are present at each management site before starting predator control. Kereru are naturally long-lived (>10 years) (Clout *et al.*, 1995) so have the potential to successfully fledge many chicks in a life-time providing they survive. At sites where adult mortality is high,

protecting adult kereru may be a priority before focusing on nest predators. As cats are a significant threat in urban-rural areas, cat owners need to be advised of the potential threat their cats pose to kereru and how to prevent their cat predated kereru (see Prendergast (2006) for more detail). Community involvement in trapping programmes should be encouraged by providing land owners with traps and educating them on how to trap strategically (i.e. around kereru nests) and humanely.

2. Habitat restoration/enhancement

Existing kereru habitat can be enhanced by planting additional food species. It is also necessary to create new habitat in areas currently unsuitable for kereru. A diverse range of plant species that provide food year-round needs to be available. Kereru are able to disperse over large distances, so colonisation of areas where high quality habitat is available is likely to be quite rapid if existing populations can be increased. Landowners should be encouraged to participate in habitat enhancement. This can be done by making information on plant species suitable for cultivation available e.g. through community meetings, workshops, pamphlets and websites. Information provided about each plant species could include tips about cultivation, food types that are eaten by kereru (and perhaps other birds) and what time of year these food types are available to kereru.

3. Fencing of forest fragments

Most kereru food species are palatable to stock and therefore lacking in the understory of many forest fragments in the Akaroa area (pers. obs.). Fencing of forest fragments will prevent stock from eating saplings and therefore increase the diversity of species available in each forest stratum. It is necessary to educate landowners about the ecological, aesthetic, and economic benefits of fencing native forest. Sources of information about ways to protect native habitat (e.g. QEII national trust, local government websites, forest and bird, DOC) need to be made readily available.

4. Educating the community about how to prevent car strike

When kereru are feeding in tree lucerne or broom on roadsides they are vulnerable to collision with motor vehicles (M. Schotborgh and J. McIlroy, *pers. comm.*). Although vegetation on roadsides can be an important food source for kereru, the council should be encouraged to clear tree lucerne and broom adjacent to roads. However, they should also be encouraged to mitigate this by planting other preferred species nearby.

8.7.2 The value of introduced plant species in habitat restoration

One of the common themes of this study and Schotborgh (2005) is that both native and introduced plant species are important to kereru. While native fruits are still considered to be of most value to kereru, introduced species such as broom, tree lucerne, willow and fruit trees are of considerable value during winter, spring and early summer. The ideal situation on Banks Peninsula, where native fruit is not available year-round, is to plant mixed habitats of native and introduced species.

There are two problems with this approach. The first is that this may increase the spread of introduced plants with fleshy fruits into existing forest fragments. The second is that it conflicts with advice from government research agencies (DOC; Manaaki Whenua), local government bodies and organisations such as Forest and Bird who advocate planting of native trees to attract native birds and protect New Zealand's biodiversity (www.biodiversity.govt.nz/involved/help/backyard/).

I suggest that broom and tree lucerne are the only introduced species necessary for significant enhancement of kereru habitat if a wide range of native fruiting species and kowhai are made available. As neither of these species are dispersed by kereru or can compete with native species (H. D. Wilson, *pers. comm.*) this will eliminate the possibility of introduced plant species spreading into native forest. Introduced species which are good foods for kereru and other birds such as tui (Powlesland *et al.*, *in progress*) and bellbird (Ridley, 1998) could be promoted to the public without detracting from the value of native species. It would be necessary to only advocate non-invasive species that would be of high value to native birds.

8.8 Future Research

- With long-life radio transmitters available it is now possible to study individual radio-tagged kereru for up to six years (www.sirtrack.com). Studies longer than 2 years would be beneficial for better understanding seasonal movements, home ranges and food species. It would greatly help to determine whether kereru repeat movements every year and if there is variation between years due to changes in food availability.
- Information is needed on the impact of introduced mammalian predators on breeding kereru and population dynamics in regenerating forest fragments. Studies on Banks Peninsula should include Hinewai Reserve because it is the largest forest fragment and

because some data is already available. There should be comparison of areas where predators are controlled and areas with no control.

- Monitoring of sites after management has been implemented will be needed to assess the success of management. Radio-tagged kereru can be used to replicate this study and Schotborgh (2005) at key sites. Suggested time frames for monitoring using radio-tracking are five years after predator control and 10-15 year after re-vegetation. Less intensive monitoring methods that can be applied at all sites over the peninsula (see section 8.4) can be used to assess whether significant population growth has occurred.
- Research on the nutritional value of kowhai and introduced legumes such as tree lucerne and broom needs to be carried out to determine if introduced legumes may be of more value as foods for kereru. It would also be useful to compare the nutritional value of new leaves of introduced deciduous trees with native species such as mahoe, ribbonwood, lacebark, wineberry and pohuehue.
- Detailed phenology monitoring of kereru food species should be included in subsequent studies to get a better understanding of feeding preferences. This is also essential for interpretation of population trends and breeding patterns (Mander *et al.*, 1998).
- Research needs to be done on how to accurately assess habitat quality for kereru. The relationship between habitat quality and density of kereru in study areas and how this relates to home range size needs to be investigated. Studies to date have not teased these factors apart because the density of kereru has not been measured at any of the study sites. Only recently have studies on kereru (Hill, 2003; Schotborgh, 2005; present study) begun trying to comprehensively assess habitat quality.
- It would be useful to investigate the main factors causing window strike. Reports from Banks Peninsula residents indicate that this is not uncommon for kereru to fly into windows (B. Narbey and A. Spencer, *pers. comm.*). While it is possible to make windows more visible by putting stickers on them, many people may prefer a more aesthetic alternative.

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Appendix 1

Frequency, sex (determined only for breeding kereru), date of capture, catch site, area of residence (area containing >90% of location fixes) and number of observation periods (n) for each kereru.

Frequency	Sex	Date of capture	Catch Site	Area of residence	n
40	F	18.03.05	Otanerito	LV	78
42	F	18.03.05	Otanerito	LV	62
44	F	25.02.05	Otanerito	LV	116
46	M	17.03.05	Otanerito	LV	105
48	–	17.03.05	Otanerito	LV	87
50	M	06.04.05	PPS	PPS	59
52	–	22.03.05	PPS	AK	69
54	–	06.04.05	PPS	AK	77
56	–	06.04.05	PPS	PPS	41
58	F	25.02.05	Otanerito	LV	118
60	M	18.02.05	Otanerito	LV	42
62	F	22.03.05	PPS	SB	74
64	–	25.02.05	Otanerito	LV	111
66	F	22.03.05	PPS	AK	54
68	–	25.02.05	Otanerito	LV	42

Otanerito=Area around Otanerito Homestead, lower Otanerito Valley

LV = lower Otanerito Valley

PPS = upper Otanerito Valley near Purple Peak Saddle

AK = Akaroa

SB = Sleepy Bay gully

Appendix 2

Data sheet used to record observations

Date.....

Weather.....

#	Time	Plant species	Activity	Food type	Perch type	Stratum	Bird ht	Canopy ht	Habitat	Untagged	Comments

Appendix 3

Proportion of feeding observations recorded on each species (A) and proportion of kereru recorded eating each species (B) at three sites. Shaded values are above the 0.4 threshold.

Otanerito Valley

A

	2005												2006											
	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb											
Apple								0.03							Apple									
Broom						0.1	0.1	0.1	0.2	0.2	0.5	0.5	0.6	0.4	0.8	0.3	Broom							
Cherry Plum									0.1								Cherry Plum							
Karamu			0.1														Karamu							
Five-finger													0.05				Five-finger							
Fuchsia													0.1		0.1		Fuchsia							
Kaikomako		0.1	0.04														Kaikomako							
Kakabeak								0.0									Kakabeak							
Kawakawa	0.3	0.1	0.04	0.04													Kawakawa							
Kowhai						0.1	0.4	0.2	0.4	0.4	0.4	0.4	0.1	0.2	0.2	0.3	0.2	0.1	0.1	0.1	0.05	Kowhai		
Mahoe	0.2	0.2	0.4	0.3	0.3	0.4	0.3	0.1	0.1												0.1	0.1	0.1	Mahoe
Ngaio		0.1	0.2	0.1	0.1	0.1															0.1	0.2		Ngaio
Pate				0.04																				Pate
Pigeonwood		0.1																			0.2	0.4	0.1	Pigeonwood
Plum											0.05													Plum
Pohuehue						0.2	0.0	0.1	0.1	0.1	0.1				0.1									Pohuehue
Poroporo	0.5	0.5	0.04	0.2																		0.2	0.4	Poroporo
Ribbonwood								0.1	0.04															Ribbonwood
Rohutu				0.2	0.2	0.5	0.3	0.1																Rohutu
Supplejack		0.1																						Supplejack
Titoki																								Titoki
Tree Lucerne						0.1	0.1	0.3	0.3	0.04	0.4	0.1	0.1	0.2	0.10		0.04	0.1	0.1	0.05	0.05			Tree Lucerne
Willow									0.3		0.3	0.2	0.1	0.1	0.1									Willow
Wineberry																							0.05	Wineberry

B

	2005												2006											
	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb											
Apple									0.1															Apple
Broom						0.2	0.1	0.1	0.3	0.3	0.4	0.5	0.5	0.6	0.5	0.5	0.3							Broom
Cherry Plum									0.1															Cherry Plum
Karamu			0.1																					Karamu
Five-finger																	0.1							Five-finger
Fuchsia																	0.1							Fuchsia
Kaikomako		0.2	0.1																					Kaikomako
Kakabeak								0.1																Kakabeak
Kawakawa	0.5	0.4	0.1	0.2																				Kawakawa
Kowhai						0.2	0.3	0.3	0.5	0.5	0.3	0.3	0.2	0.3	0.3	0.4	0.3	0.2		0.1	0.2	0.1		Kowhai
Mahoe	0.3	0.4	0.6	0.4	0.4	0.5	0.4	0.1	0.2												0.1	0.1	0.2	Mahoe
Ngaio		0.2	0.4	0.2	0.1	0.1															0.1	0.2		Ngaio
Pate				0.1																				Pate
Pigeonwood		0.2																			0.1	0.3	0.2	Pigeonwood
Plum												0.1												Plum
Pohuehue		0.2				0.3	0.1	0.2	0.2	0.1	0.1				0.1									Pohuehue
Poroporo	0.8	1.0	0.1	0.4																		0.3	0.5	Poroporo
Ribbonwood								0.1	0.1															Ribbonwood
Rohutu				0.2	0.3	0.5	0.3	0.2																Rohutu
Supplejack		0.2																						Supplejack
Titoki																								Titoki
Tree Lucerne						0.1	0.1	0.2	0.2	0.1	0.5	0.2	0.1	0.1	0.1		0.1	0.1	0.1	0.1	0.1	0.1		Tree Lucerne
Willow									0.3		0.3	0.3	0.2	0.1	0.1									Willow
Wineberry																							0.1	Wineberry

Purple Peak Saddle

A

Food species	2005										2006		Food species	
	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb			
Broadleaf						0.2	0.5						Broadleaf	
Broom		0.3	0.3	0.7	0.5	1.0	0.8	0.5	1.0	1.0	1.0	1.0	Broom	
Fuchsia											1.0	1.0	1.0	Fuchsia
Horopito	1.0	1.0	0.5	0.7									Horopito	
Kowhai			0.7	1.0	0.3								Kowhai	
Mahoe		0.5											Mahoe	
Tree Lucerne					0.5								Tree Lucerne	

B

Food species	2005										2006		Food species	
	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb			
Broom		1	1	1	1	1	1	1	1	1	1	1	Broom	
Fuchsia											1	1	1	Fuchsia
Broadleaf							1	1					Broadleaf	
Horopito	1	1	1	1									Horopito	
Kowhai			1	1	1								Kowhai	
Mahoe		1											Mahoe	
Tree Lucerne					1								Tree Lucerne	

Akaroa

A

Food species	2005										2006		Food species	
	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb		
Apple							0.1						Apple	
Apricot										0.3			Apricot	
Ash		0.2											Ash	
Broom							0.4	0.2		0.3			Broom	
Cabbage tree		0.2											Cabbage tree	
Corokia x			0.2										Corokia x	
Cotoneaster				0.2									Cotoneaster	
Fuchsia											0.5	0.5	0.3	Fuchsia
Hawthorn			0.2										Hawthorn	
Holly			0.3										Holly	
Horopito	0.4												Horopito	
Lophomyrtus x			0.5										Lophomyrtus x	
Mahoe	0.1	0.2	0.1	0.2	0.1	0.3							Mahoe	
Ngaio	0.4	0.6	0.6	0.3	0.2								Ngaio	
Plum								0.3	0.2		0.3	0.5	0.3	Plum
Pohuehue				0.3										Pohuehue
Poplar									0.9	0.8	0.8	0.3		Poplar
Silver Birch		0.2												Silver Birch
Tree Lucerne			0.3	0.4	0.6	0.7	1.0	1.0	1.0	1.0	0.5			Tree Lucerne
Willow								0.1	0.1					Willow
Wineberry												0.3	0.3	Wineberry

B

	2005											2006			
	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb			
Apple							0.3							Apple	
Apricot									0.3					Apricot	
Ash		0.5												Ash	
Broom							0.7	0.3		0.5				Broom	
Cabbage			0.3											Cabbage	
Corokia x				0.3										Corokia x	
Cotoneaster					0.3									Cotoneaster	
Fuschia										0.5	0.3	0.5	0.5	Fuschia	
Hawthorn			0.3											Hawthorn	
Holly			0.3											Holly	
Horopito	0.5													Horopito	
Lophomyrtus x				0.3										Lophomyrtus x	
Mahoe	0.5	0.3	0.3		0.3	0.3	0.3							Mahoe	
Ngaio	0.5	1.0	1.0	0.3		0.3								Ngaio	
Plum								0.3	0.3		0.3	0.5	0.3	Plum	
Pohuehue					0.3									Pohuehue	
Poplar									0.7	1.0	0.5	0.3		Poplar	
Silver Birch		0.5												Silver Birch	
Tree Lucerne			0.3	0.3	0.7	0.7	1.0	1.0	1.0	1.0	0.7	0.3	0.3	Tree Lucerne	
Willow								0.3	0.3			0.7	0.3	Willow	
Wineberry													0.5	0.5	Wineberry

Appendix 4

Full list of species eaten by kereru in Akaroa and Otanerito Valley and food species not eaten by kereru in this study but which are present on Banks Peninsula.

apple (<i>Malus spp.</i>)	lacebark (<i>Hoheria populnea</i>)
apricot (<i>Prunus sp.</i>)	<i>Lophomyrtus obcordata x bullata</i>
ash (<i>Fraxinus sp.</i>)	mahoe (<i>Melicytus ramiflorus</i>)
broadleaf (<i>Griselinia littoralis</i>),	matai (<i>Prumnopitys taxifolia</i>)
broom (<i>Cytisus scoparius</i>)	ngaio (<i>Myoporum laetum</i>)
cabbage tree (<i>Cordyline australis</i>)	nikau (<i>Rhopalostylis sapida</i>)
cherry (<i>Prunus spp.</i>)	pate (<i>Schefflera digitata</i>)
cherry plum (<i>Prunus spp.</i>)	pigeonwood (<i>Hedycarya arborea</i>)
<i>Coprosma spp.</i>	phoenix palm (<i>Phoenix canariensis</i>)
<i>Corokia buddleioides x C. cotoneaster</i>	plum (<i>Prunus sp.</i>)
cotoneaster (<i>Cotoneaster sp.</i>)	pohuehue (<i>Muehlenbeckia australis</i>)
crab apple (<i>Malus sp.</i>)	poplar (<i>Populus nigra italica</i>)
five-finger (<i>Pseudopanax aboreus</i>)	poroporo (<i>Solanum aviculare; S. laciniatum</i>)
fuchsia (<i>Fuchsia excorticata</i>)	ribbonwood (<i>Plagianthus regius</i>)
hawthorn (<i>Crataegus oxycantha</i>)	rohutu (<i>Lophomyrtus obcordata</i>)
holly (<i>Ilex sp.</i>)	silver birch (<i>Betula pendula</i>)
horopito (<i>Pseudowintera colorata</i>)	supplejack (<i>Ripogonum scandens</i>)
kakabeak (<i>Clianthus puniceus</i>)	titoki (<i>Alectryon excelsus</i>)
kaikomako (<i>Pennantia corymbosa</i>)	tree lucerne (<i>Chamaecytisus palmensis</i>)
karamu (<i>Coprosma robusta</i>)	virgilia (<i>Virgilia oroboides</i>)
kawakawa (<i>Macropiper excelsum</i>)	willow (<i>Salix sp.</i>)
kohuhu (<i>Pittosporum tenuifolium</i>)	wineberry (<i>Aristotelia serrata</i>)
kowhai (<i>Sophora microphylla</i>)	yew (<i>Taxus baccata</i>)
laburnum (<i>Laburnum anagyroides</i>)	

Food species not eaten during this study but which are found on Banks Peninsula (Clout, 1990; Clout *et al.*, 1991; Dijkgraaf, 2002; McEwan, 1978; Pierce & Graham, 1995; Schotborgh, 2005):

rowan (*Sorbus aucuparia*)

kahikatea (*Dacrycarpus dacrydioides*)

red matipo (*Myrsine australis*)

Hall's totara (*Podocarpus hallii*)

karaka (*Corynocarpus laevigatus*)

cherry laurel (*Prunus laurocerasus*)

acacia (*Racosperma spp.*)

elm (*Ulmus xhollandica*)

alder (*Alnus glutinosa*)

oak (*Quercus spp.*)

chestnut (*Aesculus hippocastanum*)

walnut (*Juglans spp.*)

Appendix 5

The number of locations needed for incremental area plots of the MCP area and home ranges to reach stability. Home ranges that did not reach stability are shown with a (-).

Kereru #	MCP		Cluster Analysis			
	Annual	Annual	Breeding	Non-breeding	Fruit	No Fruit
40	90	17	55	12	13	50
42	70	-	30	-	8	40
44	120	10	-	25	10	-
46	110	-	-	-	-	60
48	95	-	-	-	34	-
50	68	-	45	38	-	-
52	70	70	-	-	30	-
54	80	80	45	-	28	55
56	42	78	-	32	-	-
58	120	120	-	44	62	40
60	42	44	17	-	42	-
62	80	78	38	7	35	-
64	120	28	65	-	27	55
66	55	-	32	-	-	27
68	42	42	15	-	42	-

Appendix 6

Notes on breeding kereru in the Akaroa and Hinewai Reserve study sites

Display flights performed by male kereru began in August 2005 and were still being observed in February 2006. The first nests of tagged kereru were found in September in Akaroa and near Purple Peak Saddle; these nests were abandoned after a snow storm (Fig 1, Table 1). Up to three nesting attempts were made by each breeding pair during the study period (February 2005-February 2006) (Fig 1). Only two pairs fledged chicks, both on the first attempt and it is not known whether they attempted to re-nest.

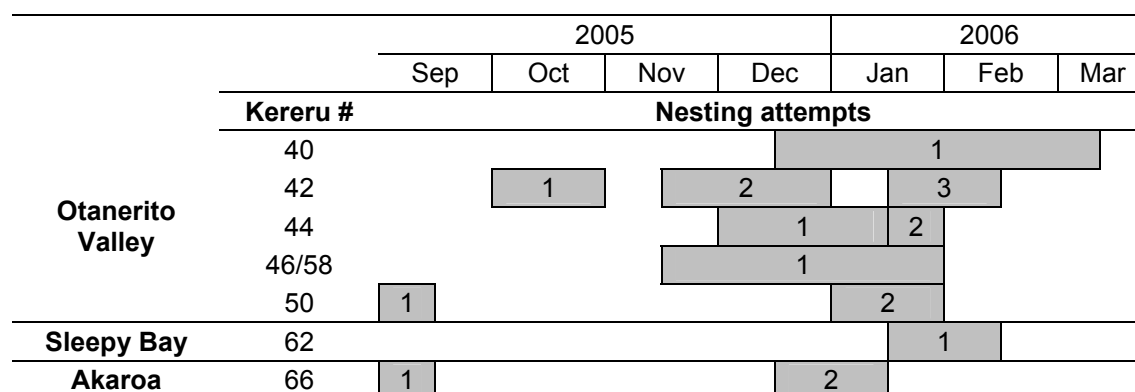


Figure 1. The timing of nesting attempts for each tagged kereru. Nesting attempts are illustrated from when an occupied nest was found to when the nest was unoccupied by an adult or chick.

Table 1. The fate of tagged kereru nests for the 2005-2006 breeding season.

	Kereru #	Nesting attempts	Nest fate	Stage at which nest failed
Otanerito Valley	40	1st	fledged	N/A
	42	1st	unknown	egg
		2nd	unknown	chick
		3rd	fell through nest	egg
	44	1st	unknown	chick
		2nd	predated	egg
46/58	1st	fledged	N/A	
50	1st	abandoned	egg	
	2nd	unknown	egg	
Sleepy Bay	62	1st	unknown	egg
Akaroa	66	1st	abandoned	egg
		2nd	unknown	egg

1st, 2nd, 3rd = the number of nesting attempts

Most nests failed at the egg stage (Table 1.). Egg remains were only recovered twice, one looked like it may have been predated by a possum (S.T. Prendergast, *pers. comm.*) and the other had fallen through a badly built nest. Other failures were recorded as ‘unknown cause’; however the lack of egg shell or chick remains in or around the nest suggests that these eggs were removed from the nest by an unknown predator. Stoats are the most likely culprit as they are known to cleanly remove eggs and chicks from the nest (Innes, 1990); shell fragments are often not found (King, 1990). Rats and possums are known to eat eggs in the nest (Innes, 1990; S. Ogilvie, *pers. comm.*).

Two tagged kereru were found dead during July 2005. The bodies of both kereru had been dragged into scrub and eaten. Only the transmitter and harness, feathers and leg jesses were recovered. It is not known whether these kereru died of natural causes (such as malnutrition, exposure or old age) and were scavenged, or whether they were predated on.

Out a total of 12 nests, only four produced chicks (33%). The fledge rate was 17%. This was lower than for kereru in Lyttelton Harbour (fledge rate of 35%) (Schotborgh, 2005) but higher than studies in Mohi Bush, Hawkes Bay and Wenderholm Regional Park, north Auckland where the fledge rate was 0% (Clout *et al.*, 1995). Predatory mammals were present at all these study sites.