ABUNDANCE AND FORAGING NICHES OF FOREST BIRDS IN PART OF THE RUAMAHANGA ECOLOGICAL AREA, TARARUA STATE FOREST PARK

A thesis presented in partial
fulfilment of the requirements for the degree
of Doctor of Philosophy
at Massey University

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ABSTRACT

To test the applicability in New Zealand of ecological theories derived from the study of northern temperate and tropical avifaunas, the bird community in part of the Ruamahanga Ecological Area, Tararua State Forest Park was studied from October 1982 until February 1985. A modified five-minute bird count to determine the relative abundances of each bird species with a near/far ratio proved useful in assessing the distribution of the common bird species but was inadequate for the rarer species. Twenty-nine bird species were seen, twenty-one of which probably bred within the study area. Eleven forest bird species were seen with sufficient frequency to apply the near/far. Bird species diversity was significantly correlated with foliage height diversity, but not with plant species diversity. Principal component analysis was used as a graphical tool to describe the inter-relationships of bird species distribution with plant species and plant structure in greater detail. Bird species composition was related to both the forest structure and the plant species composition. The distributions of ten common bird species were positively correlated with high canopy forest, five species with red beech-dominated forest and five species with podocarp/broadleaf-dominated forest. Many of the bird species were most abundant at the end of the breeding season in February-March. This was not apparent from consideration of the five-minute bird counts alone because of seasonal changes in conspicuousness. The modified five-minute bird counts were useful indicators of bird movement into and out of the study area. Only whiteheads showed consistent seasonal changes in altitudinal distribution, higher in summer than in winter. By determining the relative importance of foliage height, tree species and substrate bird species foraging niches were examined. Foraging site showed the greatest difference between bird species, followed by tree species and then foraging height. Comparison with other studies showed that there is a large degree of plasticity in foraging niche site between habitats in New Zealand birds. Foraging niches of congeners in Australia and New Zealand were similar. Each bird species preferred different species of trees for foraging. In winter decreased foraging niche overlaps were observed in conjunction with mixed species flocking. Studies of New Zealand birds indicate that foraging niches are sufficiently plastic for forest conservation management strategies be considered on a forest by forest basis. The plasticity of foraging niches may also account for the small proportion of introduced birds in the study area. Competition is probably important in structuring the forest bird community. Both niche breadths and niche overlaps were comparable with studies on much richer bird assemblages. Introduced birds were largely confined to forest margins and to resources which were previously used by extinct native birds, suggesting that the remaining native birds are successfully excluding introduced birds.

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CHAPTER 1

INTRODUCTION

One of the major aims of ecology is to understand the determinants of community composition. Although experimental results provide the most convincing tests of ecological theories, descriptive data from field observations are also useful (Alatalo et al. 1986). The study of birds has provided much of the data used to formulate and test ecological theories (Recher 1985a). In New Zealand the study of community ecology in forest birds has been neglected (Gill 1980). New Zealand is a group of isolated islands with relatively few native land birds, where a large part of the avifauna has become extinct in the past 1000 years (Holdaway 1989). With the arrival of Europeans the rate of extinctions increased rapidly in conjunction with the clearing of indigenous forests for farming and the introduction of many mammals and exotic bird species (Holdaway 1989).

This study was set up to examine the bird community of an indigenous forest in the light of this historical perspective. The utility of ecological theories, derived from the study of northern temperate and tropical avifaunas, could be investigated on what may be described as a large natural experiment.

1.1 Aims

Many ecologists think that competition is, or has been, the most important factor in community organization (Roughgarden 1983, Schoener 1983). Support for the importance of competition in bird communities comes from experimental (Minot 1981, Alatalo et al. 1985), observational (Alatalo 1981b, 1982, Bell 1985) and comparative work (Alatalo et al. 1986). Others consider the evidence for competition to be weak (Simberloff 1983, Strong 1983). There is little or no evidence of interspecific competition in some areas (Wiens and Rotenberry 1981, Mountainspring and Scott 1985) or seasons (Rosenberg et al. 1982, Brawn et al. 1987).

In observational studies evidence for competition has been suggested by:

1. Searching for niche shifts concomitant with changes in guild composition (Alerstam et al. 1974, Hogstad 1978, Alatalo 1981b, Alatalo et al. 1985, Rabol 1987).
2. Complementarity of foraging niche axes (Cody 1974a, Schoener 1974, Pianka 1978).
3. Seasonal changes in niche use (Ulfstrand 1977, Alatalo 1980, 1982 Wagner 1981, Bell 1985, Laurent 1986).
4. Niche expansion on islands as compared to the mainland (MacArthur and Wilson 1967, Diamond 1970, Alatalo et al. 1985).

A major aim of the present study was to determine the importance of competition in structuring a New Zealand forest bird community, and each of the above points were considered.

The majority of community studies, especially those of forest birds, are undertaken during the breeding season. Many birds are territorial when breeding, and the males are usually conspicuous, aiding population quantification and niche study. However, important factors determining the occurrence and abundance of birds in temperate regions act outside the breeding season (Lack 1954,1966, Fretwell 1972). As birds generally breed when food is most abundant, competition for food at this time of year may be reduced or absent (Rosenberg et al. 1982). Therefore investigations of community structure should cover the whole year.

It has been suggested that vegetation structure coupled with food resource availability and abundance, provide particular combinations of foraging opportunities for birds that in turn determine which bird species can forage successfully and survive there (Holmes and Recher 1986b). The foraging opportunities available to forest birds are influenced by tree species (Holmes and Robinson 1981, Virkkala 1988), foliage height (Pearson 1971, Holmes et al. 1979, Beedy 1981, Frith 1984), the site or substrate (Landres and MacMahon 1980, Moreno 1981, Alatalo 1982, Airola and Barrett 1985, Holmes and Recher 1986a, Carrascal et al. 1987), and foraging technique (Robinson and Holmes 1982, Holmes and Robinson 1988). Generalizations about the relative importance of these factors in structuring forest bird communities require more information. I studied height, tree species and substrate utilisation. The tree species preference of bird species were measured to identify which tree species were important for each bird species.

Biogeographical theory predicts that species on islands will have larger niches than congeners on the mainland (MacArthur and Wilson 1967, Diamond 1970). It is assumed that where there are fewer species there are fewer competitors, and competitive release results in broader niches. This theory was tested by comparing niches of species common to both Australia (mainland) and New Zealand (island). Additionally, in New Zealand the recent extinction of several bird species and introduction of many others has meant that the proportion of exotic birds within the forest bird community could be quite large. As a result of these changes the bird community may be in a state of flux. For these reasons the integration of the introduced birds with the native birds was examined.

MacArthur and MacArthur (1961) used diversity measures to show that the structural complexity of the environment was related to the number of bird species in that environment. Numerous researchers have verified this relationship (MacArthur 1964, Recher 1969, Karr and Roth 1971, Rov 1975, Beedy 1981), but others have not found strong correlations between bird species diversity and foliage height diversity (Tomoff 1974, Willson 1974, Carothers et. al. 1974, Pearson 1975, 1977, Roth 1976, Erdelen 1984, Ralph 1985). Studies of bird communities using detailed multivariate statistics have tended to concentrate on the structural features of their habitats (James 1971, Anderson and Shugart 1974, Collins et al. 1982, James and Wamer 1982, Mehlop and Lynch 1986). In these studies the most significant structural determinants of bird species distributions were associated with canopy size. Variables which measured tree species compositions were confined to a few summary measures such as percent conifers and tree species richness; but where these variables were included they were also important in distinguishing bird species groupings.

Recher (1985b) stated that the ultimate goal of ecologists is to produce a general theory which will explain patterns and predict the consequences of changes to the environment. It is apparent that both the physical structure and the species composition of the vegetation are important parameters in bird community relationships (Cody 1974a). Gilmore (1985) showed that plant species composition and plant species structure tend to vary concurrently but structure is the important factor in determining bird species distribution, I tested the applicability of this hypothesis within my study area.

Mixed species flocking, particularly in winter or the non-breeding seasons, is a common phenomenon (Morse 1970). Optimal foraging theory (Pyke et al. 1977) suggests that the individuals in mixed species flocks must be maximising their Darwinian fitness. Morse (1978) presented a model for the presumed advantages of mixed species flocking. If overlap in foraging increases then mixed species flocking is food mediated. Factors such as copying the foraging activity of other species and increased flushing of prey will be important. Conversely, if overlap decreases then mixed species flocking may be predator mediated. The relevance of these models to foraging niche complementarity in the study area during winter was assessed.

1.2 Analysis

A variety of analytical techniques were used in this thesis. A short description of the techniques used, together with the reasons for selecting each technique, follows.

Diversity, evenness, niche breadth and niche overlap

Diversity indices were calculated using the Shannon-Weaver diversity formula (Shannon and Weaver 1949). The Shannon-Weaver equation is:

$$H = \sum_{i=1}^{s} p_i \ln p_i$$

where s is the number of categories and p_i the proportion of individuals in the i^{th} category. This index varies less with sample size than the indices of Simpson (1949) or Hill (1973) (Beedy 1981). The Shannon-Weaver equation was used to measure both diversity and niche breadth. Pielou (1966) noted that among all communities containing a fixed number of species (s), diversity is maximum when all the species are equally abundant and that the maximum diversity (Hmax) is equal to the natural logarithm of the total number of species. This observation led her to define evenness (J) as the ratio of the diversity index of the community to the maximum possible diversity of that community:

$$J = H/Hmax = H/Ln(s)$$

The index of overlap used to measure coincidence of distribution was:

$$C_{ih} = 1 - 0.5 \sum_{j} | p_{ij} - p_{hj} |$$

(Schoener 1970) where p_{ij} is the proportion of species i in resource state j and p_{hj} is the proportion of species h in the same resource state. Overlap is 0 (minimum) when two species, i and h, share no resource states, and 1 (maximum) when the proportional distributions of two species among the resource states are identical.

The most common criticism of these simple measures in niche analyses is that they do not take into account resource availability (Colwell and Futuyma 1971, Hurlbert 1978, Petraitis 1979, Feinsinger et al. 1981). These authors suggest the use of measures weighted by resource availability. They assume either that total resource availability can be measured or that resource availability is proportional to resource use by the entire community. Colwell and Futuyma (1971) point out that: "Unless resource states have ecologically equivalent degrees of distinctness among them, comparisons between communities and particularly within communities, are perilous." They also discuss the problems associated with obtaining adequate measures of individual species niches.

In my study the feeding niches of the individual species within the community were assumed to be related to their use of different substrates for active foraging. Measurement of the total amount of each substrate available was not possible. The relationship of total bird community use to the actual substrates available is unknown and to assume that they are available in proportion to the total bird community use is dangerous. Because of these factors I used the simple unweighted measures of niche breadth and overlap.

Multivariate analyses

All compound indices, such as diversity and evenness, have the disadvantage that they combine the effects of variables that individually may be of biological interest (Pielou 1969). Multivariate analyses allow us to describe the relationships between a large number of variables. Complex interactions between bird species, plant species and vegetational structure can be distinguished. The consequent predictions can be of great value in resource management. However, before the application of such tests, it is essential to have some understanding of their theory, methodology, and limitations.

In principal component analysis (PCA) the principal components are derived by eigen analysis of the correlation matrix of the original variables. Each component represents a portion of the generalized variance present in the original data set. Successive components account for decreasing proportions of the variance while remaining uncorrelated with previous components (Rummel 1970, Pielou 1977). PCA is often used as an ordination method in ecological studies (James 1971, Smith 1977, Whitmore 1975, Rotenberry and Wiens 1980, Maurer et al. 1981, Collins et al. 1982, James and Wamer 1982, Anderson et al. 1983). Such an ordination is a "success" if a large proportion of the variation in the original data set is explained by the first two or three principal components (Pielou 1984). The original variables can be projected onto this two or three dimensional frame, to reveal the pattern of the data, by plotting the eigen values of each variable. Gauch (1982) has shown that this type of plot also reduces "noise" associated with stochastic variations in the data set.

Johnson (1981) described three specific problems associated with PCA.

First, the analysis may seem better than it actually is because of the presence of a large number of redundant variables. Second, it is not always easy to relate the derived factors back to the original data set. Third, the principal components are not necessarily related to how the animal perceives its environment. Karr and Martin (1981) produced similar results from PCA of both real and random data, emphasising the need for careful interpretation of results. They concluded that when the amount of variation explained by the first two principal components was similar to that for a random number set biological interpretations were questionable.

Multivariate techniques assume that the data are normally distributed. The effect of non-normality and non-homogeneous variance are decreased with large samples (Green 1979), but transformations are often necessary (Dunn 1981). These transformations may have little advantage but should be carried out if the statistical assumptions are clearly violated (Johnson 1981). Non-linear response by species to variables is a particular problem in PCA because linear combinations of variables are produced. A non-linear data swarm when projected into two dimensions may give a misleading picture of the data. The most common effect occurs when a series of samples has been taken along an environmental gradient, such as a mountain slope, where the species respond independently in a Gaussian (normal curves) fashion. The pattern produced by PCA exhibits an arch or horseshoe shape (Pielou 1984). Hill (1979a) described this arch as a mathematical artifact and devised a technique called detrended correspondence analysis (DCA) to overcome it. Other researchers regard the arch as an inherent property of successive replacement data which must be considered in any discussion or analysis of such data (Noy-Meir and Austin 1970, Swan 1970, Pielou 1977, 1984, Wartenberg et al. 1987). Wartenberg et al. (1987) recommend reporting the arch unscaled in two dimensions, even though it is a one dimensional form.

Despite flagrant violations of statistical assumptions multivariate techniques have been useful in defining community structure. Johnson (1981) concluded that there were two possible explanations for this apparent inconsistency. Either biologists were reporting the results of sophisticated analyses only when they were in accord with their biological intuition and other results, or the tests may be more statistically robust than is recognized.

In this thesis two different types of PCA have been used, both of which present the inter-relationships between the individuals and variables of data matrices in a single figure. In the first the structure produced is based on the first two principal components derived from analysis of the data set. The variables are plotted on the same graph as the individuals by scaling both by the latent roots. The principal component scores are divided by the square root of the latent roots, whereas the latent vectors are multiplied by the square root of the latent roots. On such a graph points or lines which are close together are positively correlated, those at opposite sides are negatively correlated and those at right angles are not correlated. The length of a variable line indicates the proportion of the variation of that variable that is described by the first two principal components. The longer the line the greater the proportion of the variation that is explained (Hassard unpubl.).

The second type of PCA is a partitioning method applied to reciprocal averaging ordination (RA). RA is also known as correspondence analysis. In this technique the variables and the individuals are ordinated simultaneously. Scores are assigned to each in such a way as to maximize the correlation between individuals and variables. Hill (1979b) developed a partitioning procedure called two way indicator species analysis (TWINSPAN). A series of one dimensional RA ordinations is used to split the data into several classes. The resultant classification is considered to be more natural than standard PCA because "indifferent" species do not affect the results. However, the cost of these refinements is that the number of possible modified forms increases exponentially and choosing between them becomes increasingly subjective (Pielou 1984). Additionally, because the analysis attempts to ordinate the data into a one dimensional space, problems associated with erroneous calculations of the arch effect may arise. Although TWINSPAN is a useful technique for producing forest-type maps, the desire to produce a divisive classification may obscure the "real" situation. Changes in the selection of pseudospecies cut levels and the levels at which species and site groupings are determined can markedly alter the final output. These subjective decisions can be chosen so that the final classification agrees with the analyst's preconceived notions. PCA offers a more objective alternative. TWINSPAN is commonly used to classify vegetational groups on a proportional basis. The relative density of each plant species at each station is used rather than the absolute density.

The use of PCA and TWINSPAN in conjunction should decrease the chance of misinterpreting community structure. To satisfy the assumption of normality data were transformed before PCA by adding one to each data point and then taking the natural logarithm. TWINSPAN was performed on the raw data. The pseudospecies cut levels were calculated to correspond with the default cut levels for percentage data with one additional cut level at 50%. This allowed stations to be differentiated by plant species density in addition to plant species composition. FHD and PSD were also calculated at each station.

Cluster analysis

Studies of the foraging ecology of forest bird communities are numerous. Several authors have divided the individual species of their bird communities into guilds (Willson 1974, Herrera 1978, Holmes et al. 1979, Eckhardt 1979, Landres and MacMahon 1980). A guild is a subset of the community in which individuals use a similar class of resources in a similar manner (Root 1967). Grouping species into guilds facilitates recognition of community organization and identifies the most probable competitors (Landres and MacMahon 1980). Guilds are identified by several techniques. Some authors assign guilds subjectively on the basis of known substrate preferences (Willson 1974, Herrera 1978, Eckhardt 1979); others use cluster analysis of the resource states used by each species to formalize guild structure (Holmes et al. 1979, Landres and MacMahon 1980, Holmes and Recher 1986b). The latter approach has been used in this thesis because it provides an objective estimation of possible competition.

May (1975) pointed out the danger of estimating the overlap in niche by the use of aggregated measurements of individual resources. Clustering techniques based on euclidean distances calculated from aggregated data sets overestimate the similarity coefficients. In my study both the single axis and the multi-dimensional niche breadths and overlaps were calculated, aggregated measures were not used. A major problem occurs with the use of euclidean distances on sparse data matrices. The euclidean distance between two sparse quadrats, or rare species, may be quite small despite the fact that none of the variables overlap. I overcame this problem by calculating the overlap between species or stations (Schoener 1970), and used the proportional overlaps as a similarity matrix for cluster analysis.

Various types of cluster analysis are available (Review by Pielou 1984). The groups defined in cluster analysis are defined by the clustering algorithm used. In this thesis the unweighted pair group mean clustering technique was used.

1.3 The study area

The study area is located on the north eastern slopes of the Tararua Range (Fig. 1.1). The area was chosen because it contains a variety of forest types and forests structures which have not been modified by logging. The response of the avifauna to this diversity was investigated. The peaks of the Tararua range vary from 1,200m to 1,500m and are covered with alpine scrub. The majority of the range lies within Tararua State Forest Park. The slopes of the mountains are covered with mixed podocarp-broadleaf forest with patches of beech.

Within the study area six transects were established. Each transect comprised eight bird counting stations at intervals of approximately 200 metres (Fig. 1.1). The six transects were:

Transect 1 at 360 metres in the Mangatainoka Stream valley.

Transect 2 at 580 metres in the Mangatainoka Stream valley.

Transect 3 from the Mangatainoka forks at 360 metres to the ridge between the Mangatainoka and Ruapae catchments at 720 metres.

Transect 4 at 720 metres along the ridge between the Mangatainoka and Ruapae catchments.

Transect 5 at 580 metres in the Ruapae Stream valley.

Transect 6 from 720 metres to the top of Herepai at 1100 metres.

The transects were set up so that changes in distribution of birds at different altitudes and in the major forest types could be studied. To enable the maximum replication of count stations existing tracks were utilized in establishment of transects. The vegetation structure and composition around each station was intensively mapped in a companion study (Drummond in prep). I analysed the data collected in the botanical study to identify aspects of the vegetation that affect the birds.

The vegetation was arbitrarily divided into four tiers:

Canopy - Trees with more than 50% of the crown unshaded.

Subcanopy - Trees > 4 metres in height but under the canopy.

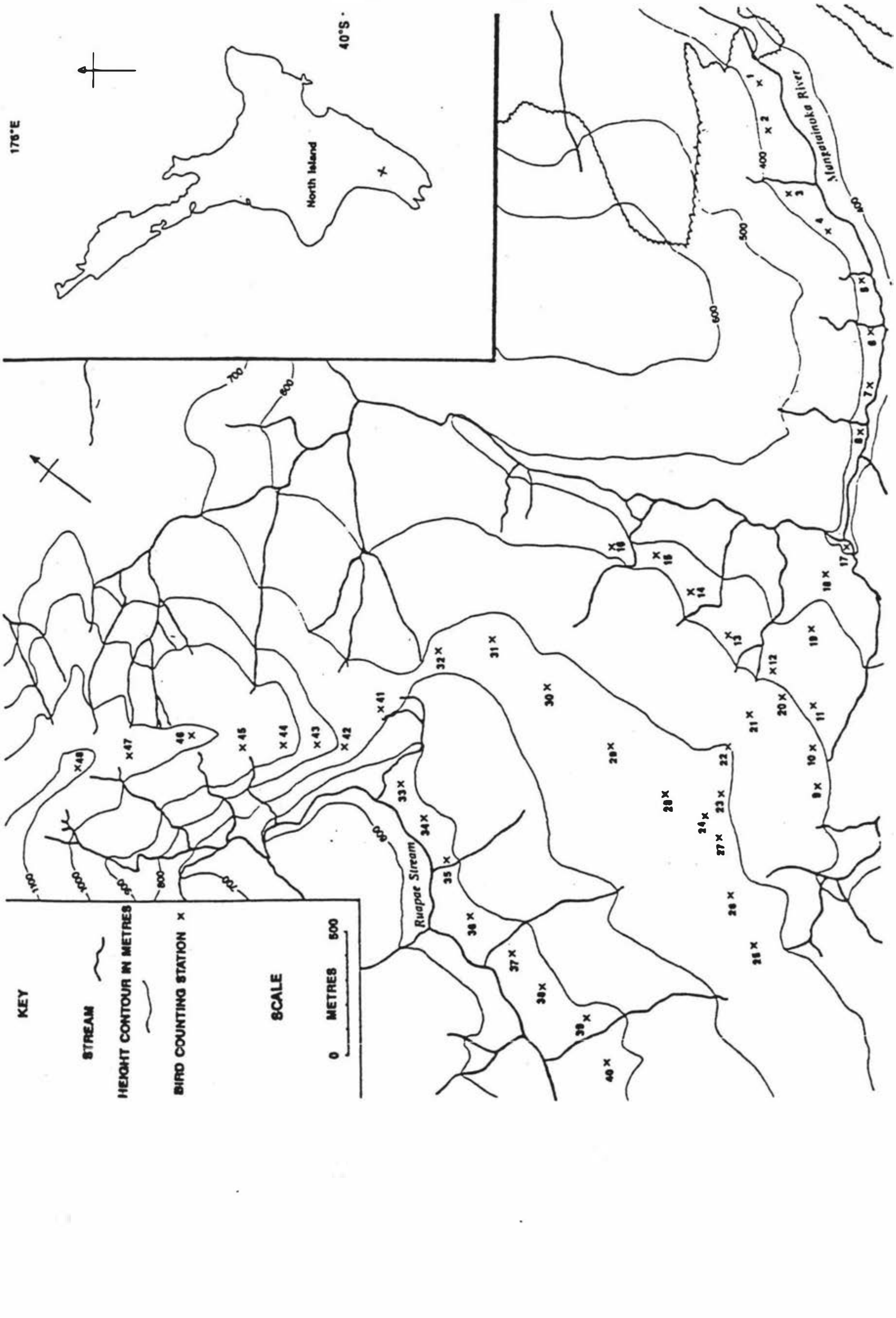
Shrub - Trees 0.5 - 4 metres in height under the canopy.

Ground - Trees < 0.5 metres in height under the canopy.

In each tier 120 trees within 40 metres of each bird counting station were identified (Appendix 1). At some of the higher altitude stations

FIGURE 1.1

Map of the Study Area



the subcanopy and shrub layers were absent or reduced and fewer than 120 trees were encountered. Point height intercept (PHI) data were also collected at 24 points within 40 metres of each station (Appendix 2). At each point a range finder was used to record the vertical foliage distribution and the tree species of each intercept. For the purposes of analysing bird/plant interactions tree ferns were grouped, the majority were Cyathea smithii with some Cyathea medularis, Dicksonia squarrosa, and Dicksonia fibrosa. Two climbing rata species, Metrosideros fulgens and Metrosideros diffusa, were also grouped. These two groups and 17 tree species comprised more than 95% of the woody vegetation in the study area (Table 1.1).

On the basis of TWINSPAN the study area was classified into five vegetational types (Fig. 1.2, Tables 1.2, 1.3), the variation within these groups was demonstrated by PCA (Figs. 1.3, 1.4, data in Appendix 1, and Appendix 2).

The upper four stations were markedly different from the rest of the study area, these stations were classified as subalpine scrub. They were characterized by an abundance of leatherwood (Olearia colensoi) and Dracophyllum filifolium, with some stinkwood (Coprosma foetidissima). Other woody species were almost absent and the average canopy height and width were each less than one metre. Consequently there was no subcanopy or shrub layer, and the canopy density was extremely high (Appendix 3). Stations 43 and 44 were more diverse than stations 45 through 48, in addition to leatherwood and Dracophyllum several of the common forest species were also present. The canopy

TABLE 1.1

The percentage occurrence of common woody species in the vegetational strata of the study area

Tree species		Canopy	Subcanopy	Shrub	Ground	P.H.I.
Dacrydium cupressinum	RIMU	6.1	0.7	1.7	0.3	3.5
Podocarpus ferrugineus	MIRO	4.5	3.8	5.7	6.0	6.4
Podocarpus hallii	HALL	2.3	3.8	7.1	1.1	2.2
Phyllocladus alpinus	PHYL	3.2	1.1	2.5	0.8	2.4
Nothofagus fusca	RBEE	15.1	5.1	1.6	3.7	13.1
Metrosideros spp.	RATA	0.0	0.0	0.6	2.9	1.4
Weinmannia racemosa	KAMA	41.8	25.4	3.8	3.7	40.8
Melicytus ramiflorus	MAHO	0.8	2.6	0.3	1.4	0.8
Myrsine salicina	TORO	6.5	39.8	6.7	14.8	9.9
Griselinia littoralis	BRDL	1.7	0.3	0.4	12.6	1.1
Elaeocarpus dentatus	HINA	0.9	0.5	1.0	2.3	0.5
Carpodetus serratus	PUTA	1.3	1.8	1.7	1.6	0.6
Pseudowintera axillaris	AXIL	0.1	3.8	6.4	1.8	1.4
Pseudowintera colorata	COLO	0.3	1.5	5.6	3.3	1.1
Coprosma foetidissima	CFOE	0.5	0.1	5.1	6.1	0.8
Coprosma polymorpha	CPOL	0.2	0.2	24.3	12.8	2.3
Olearia colensoi	OLEC	6.1	0.0	0.3	3.6	2.8
Dracophyllum filifolium	DFIL	2.5	0.0	0.3	0.6	1.2
Cyathea and *Dicksonia* spp.	TFER	1.9	7.0	13.2	0.3	3.4
Total percentages		95.8	97.5	88.3	79.7	95.7

TABLE 1.2

Two-way indicator species analysis of plant tiers

```
Species                 Station

              111111141133333132333222 222223442444444
      348125676780159034456732980120169234578129345678

MAHO  33233212312-1-1-22223222---------------1--------   0000
HINA  2-2122213242233223-2-2-2-----2--------------------   0000
PUTA  23233234322222114233212-----1121-------1--1-----   0000
RATA  233--3-2----2-12-4----322-------1-----2---------   0001
AXIL  54322232224343443222231331-1211-1-----11--------   0001
TFER  55523344423333-35543443221121-221-1-------1-----   0001
RBEE  345555554544112-1--------23-324---43-4---2------   0010
RIMU  --1--21131133332322222-422-114322323332-1-1-----   0011
MIRO  2231-3323344444334222224322235444332323221------   0011
TORO  223-144433355445445555555455555555534445521-----   0011
COLO  -1--11--1112-1-12134444123243111-1-1-1144-43----   0011
HALL  1-------1-1222232122212234234324344433334322----   010
PHYL  -----------212--1------323231333333333212422----   010
KAMA  44555555555455554555555555555545555555555442-1--   011
BRDL  333223323332233243333332232332222-2223323233--11   011
CPOL  ---21312432314342344433544554445355555533534 2---   011
CFOE  -12-121233111 32-2222213222223233444233244333122-   1
OLEC  -----------------1-----------------------122345554   1
DFIL  ---------------------------1--21---11----2224433   1

      000000000000000000000000000000000000000000001111
      000000000000000000000001111111111111111111111
      00000000000111111111111000000000000000011111
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Values denote categories of abundance defined by pseudospecies cut levels. The analysis was performed on the raw data to classify stations by plant species composition and relative density concurrently. The pseudospecies cut levels were calculated to correspond with the default cut levels for percentage data with one additional cut level at 50%. Values therefore denote the sum of each plant species present in all tiers at each station with approximate equivalence to:

- = absent 1 = 0-1% 2 = 2-4% 3 = 5-9%
4 = 10-19% 5 = 20-49% 6 = 50-100%

Vertical lines separate classes of station at level 3; horizontal lines separate classes of species at level 4. Plant species codes are in table 1.1.

TABLE 1.3

Two-way indicator species analysis of point height intercepts

```
Species                 Station

           1   1    111333113334222312 2223322234411444444
          261577346883434615759047900190232885611229345678

RATA      33-1--33-2222342131-21------------------13------   0000
PUTA      -2211-2212-122222--2----------------------------   0000
AXIL      ----1-333232----222434------------------23------   0000
TFER      34224-5544242334223222----11---------11---------   0000
MAHO      232---32-1-41-22----------------------------1----  0001
HINA      ------3-2-3--------32---------------------------   0001
RBEE      5566565556622---1-----241455-4-53---------------   001
KAMA      5655555455556666666666656555555565666565555553----   0100
TORO      ----224134-434545-544423145534534325465431------   0100
BRDL      --11-12---1212-3---22-----2-------4222222-11----   0100
RIMU      -2-1------13--3-1332322---312352-2-5442-34------   0101
MIRO      ----1---22525-1-24333--2--31552233-5433355------   0101
HALL      -------------112---2211-11-121223225334411-2----   0110
COLO      -------------312---1--------------12-344--23----   0110
CPOL      ---22-------11-----2-12234----12312415332-------   0110
PHYL      ----------------------445-322233122334--2--3----   0111
CFOE      ----------2-------------1--3-1-----2-2221143----   0111
OLEC      -----------------------------------------3--454554   1
DFIL      ------------------------1-----------------134443   1

          000000000000000000000000000000000000000000001111
          00000000000000000000001111111111111111111111
          00000000000111111111110000000000000000000011
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Values denote categories of abundance defined by pseudospecies cut levels. The analysis was performed on the raw data to classify stations by plant species composition and relative density concurrently. The pseudospecies cut levels were calculated to correspond with the default cut levels for percentage data with one additional cut level at 50%. Values therefore denote the number of intercepts of each plant species present at each station with approximate equivalence to:

- = absent 1 = 0-1% 2 = 2-4% 3 = 5-9%
4 = 10-19% 5 = 20-49% 6 = 50-100%

Vertical lines separate classes of station at level 3; horizontal lines separate classes of species at level 4. Plant species codes are in table 1.1.

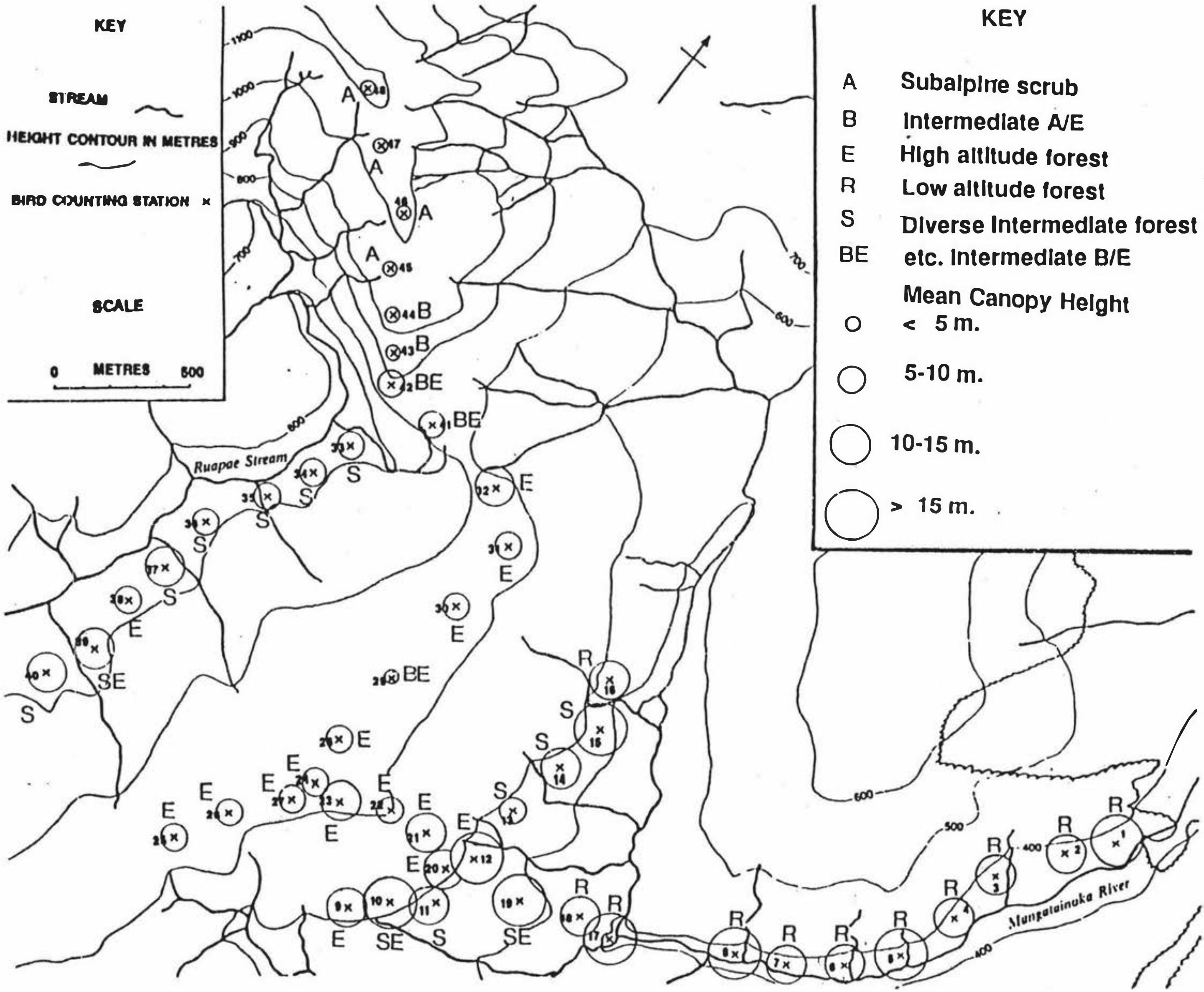

FIGURE 1.2

Forest Types and Mean Canopy Heights of Each Station

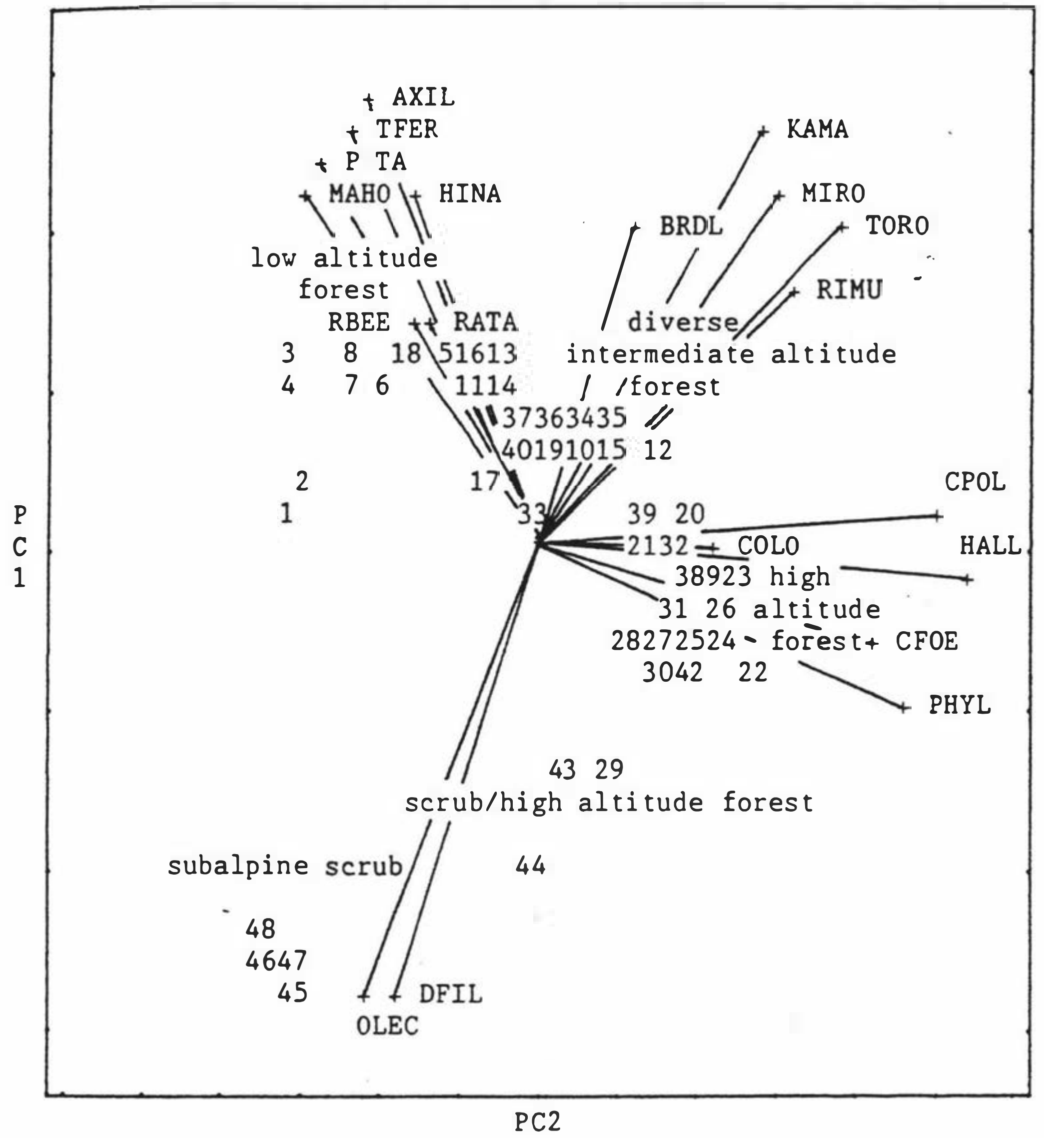

FIGURE 1.3

Principal component analysis of tree species distribution

(tiers data)

The first two principal components explained 64.1% of the variation within the data set (PC1 = 34.7%, PC2 = 29.4%). Tree species abbreviations as in table 1.1, stations are numbered. Four of the 19 variables were skewed.

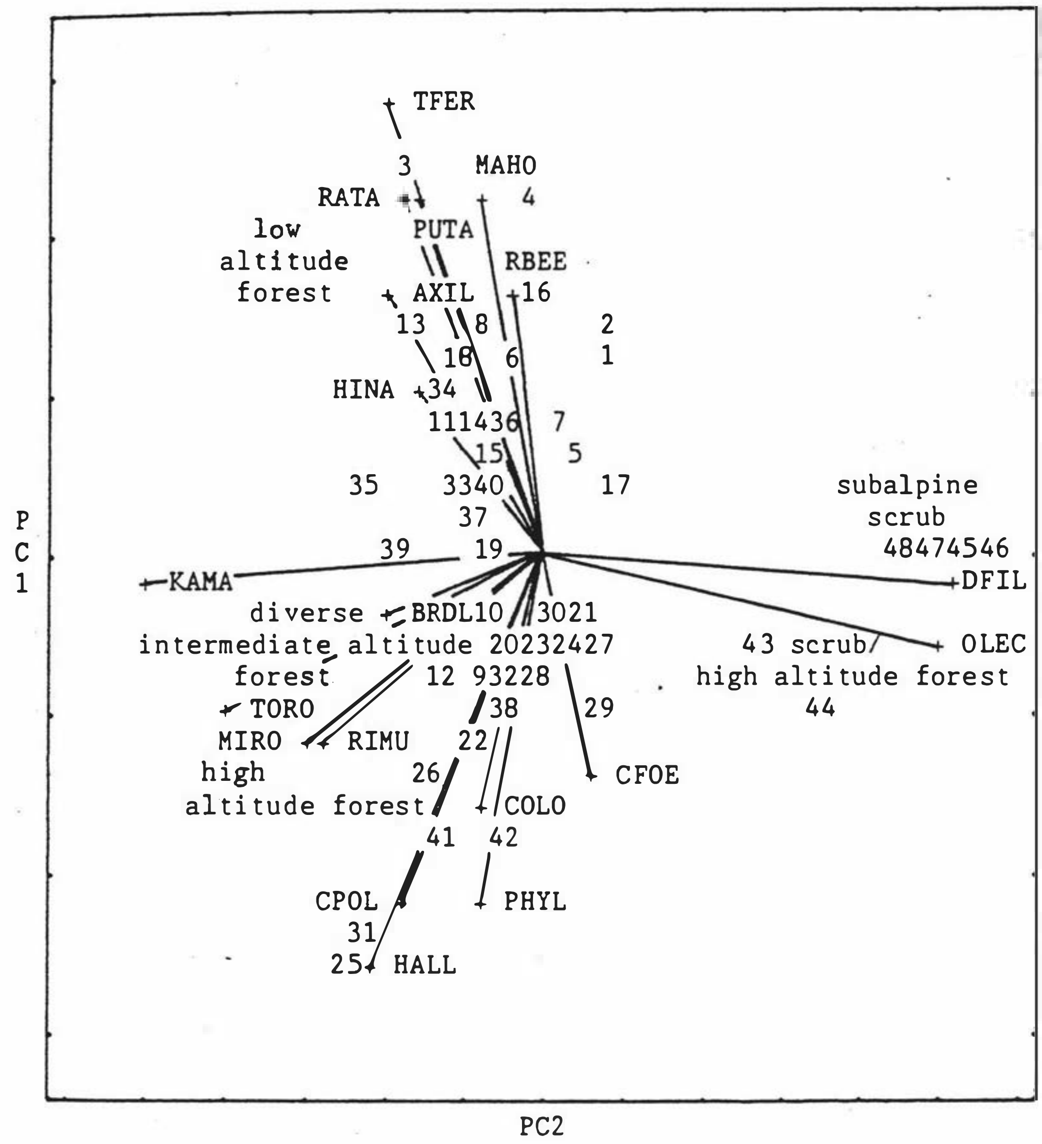

FIGURE 1.4

Principal component analysis of tree species distribution

(point height intercept data)

The first two principal components explained 47.9% of the variation within the data set (PC1 = 35.2%, PC2 = 22.7%). Tree species abbreviations as in table 1.1, stations are numbered. 14 of the 19 variables were skewed.

height at these two stations was between two and three metres. Although the subcanopy was absent some shrubs were present. These stations, and to a lesser extent stations 41, 42 and 29, were intermediate between subalpine scrub and high altitude forest.

All of the other stations in the study area were classified as forest. Kamahi (Weinmannia racemosa) was common in the canopy and the subcanopy throughout the forest. Coprosma polymorpha and broadleaf (Griselinia littoralis) were common in the shrub and ground tiers.

The stations of transect one, 16, 17 and 18 were characterized by large numbers of red beech (Nothofagus fusca) in the canopy. Mahoe (Melicytus ramiflorus), marble leaf (Carpodetus serratus), tree ferns, hinau (Elaeocarpus dentatus), climbing rata and Pseudowintera axillaris) were common in the other tiers.

Stations 11, 13, 14, 15, 33, 34, 35, 36, 37 and 40 were in diverse forest. The species found on transect one were common at these stations, with the exception of red beech which was not found at the stations in the Ruapae valley. In addition to the ubiquitous kamahi, rimu (Dacrydium cupressinum) and miro (Podocarpus ferrugineus) were common in the canopy. Toro (Myrsine salicina) and pepper tree (Pseudowintera axillaris) were common in the subcanopy and shrub layers.

The stations of transect four, 9, 12, 20, 21, 22, 23, and 38 form a group associated with high altitude forest. Mahoe, hinau, marble leaf, rata, tree ferns and P. axillaris were rare at these stations. Hall's totara (*Podocarpus hallii*), *Phyllocladus alpinus*, *Coprosma polymorpha*, *C. foetidissima*, rimu, miro and toro were common. At some of the stations along the ridge red beech was common in the canopy, but at most stations kamahi was the dominant species. Stations 10, 19, 29, 39, 41 and 42 were classified into different groups by analysis of the PHI and all tiers data and were classified as intermediate between forest types.

The graphs of the first two principal components illustrate the gradual change in forest composition with altitude and the dichotomy between the forest stations and the subalpine stations. The presence of the subalpine/scrub stations in the data set obscured the forest species inter-relationships and further analyses excluded the upper six stations (Figs. 1.5, 1.6). The PCA analyses of the PHI data described less of the total variation in the original data set than analyses of the tiers data. Many of the variables in the PHI data were skewed in violation of the statistical assumptions.

FHD was calculated from PHI data by classification of the intercept heights into 35 one metre classes. There was a high correlation between FHD and intercept height ($r = 0.91$, d.f. = 46, $p < 0.001$). This was particularly evident at the subalpine stations (Table 1.4).

TABLE 1.4

Diversity indices at each station

Station	Foliage Height Diversity		Plant Species Diversity		Bird Species Diversity.	
	H	J	H	J	H	J
1	2.890	0.820	1.846	0.429	1.699	0.708
2	2.716	0.770	2.312	0.537	1.849	0.771
3	2.801	0.794	2.275	0.529	1.790	0.746
4	2.960	0.839	2.292	0.533	1.830	0.763
5	2.901	0.823	2.443	0.568	1.782	0.743
6	2.912	0.826	2.260	0.525	1.685	0.703
7	2.999	0.850	2.562	0.595	1.795	0.749
8	3.008	0.853	2.437	0.566	1.831	0.764
9	2.729	0.774	2.240	0.520	1.355	0.565
10	2.904	0.823	2.283	0.530	1.657	0.691
11	2.550	0.723	2.397	0.557	1.849	0.771
12	2.827	0.802	2.386	0.554	1.587	0.662
13	2.760	0.783	2.401	0.558	1.605	0.669
14	2.881	0.817	2.433	0.565	1.694	0.706
15	2.876	0.815	2.312	0.537	1.775	0.740
16	2.744	0.778	2.512	0.584	1.798	0.750
17	3.200	0.907	2.356	0.547	1.710	0.713
18	3.229	0.916	2.522	0.586	1.835	0.765
19	3.134	0.889	2.425	0.563	1.646	0.686
20	2.932	0.832	2.347	0.545	1.744	0.727
21	2.409	0.683	2.334	0.542	1.863	0.777
22	2.047	0.581	2.141	0.497	1.483	0.618
23	2.438	0.691	2.237	0.520	1.299	0.542
24	1.823	0.517	2.343	0.544	1.490	0.621
25	2.151	0.610	2.263	0.526	1.146	0.478
26	2.428	0.688	2.282	0.530	1.496	0.624
27	2.541	0.721	2.271	0.528	1.134	0.473
28	1.766	0.501	2.402	0.558	1.479	0.617
29	1.907	0.541	2.314	0.538	1.907	0.795
30	2.623	0.744	1.853	0.430	1.270	0.529
31	2.197	0.623	2.134	0.496	1.543	0.644
32	2.897	0.822	2.089	0.485	1.845	0.769
33	2.487	0.705	2.326	0.540	1.158	0.483
34	2.401	0.681	2.395	0.557	1.133	0.472
35	2.436	0.691	2.357	0.548	1.206	0.503
36	2.572	0.729	2.361	0.549	1.120	0.467
37	2.534	0.719	2.272	0.528	1.195	0.498
38	2.270	0.644	1.930	0.448	0.983	0.410
39	2.672	0.758	2.193	0.509	1.213	0.506
40	2.497	0.708	2.215	0.515	1.197	0.499
41	2.468	0.700	2.101	0.488	1.920	0.801
42	2.299	0.652	2.370	0.551	1.949	0.813
43	1.499	0.425	2.431	0.565	1.435	0.598
44	1.309	0.371	2.476	0.575	1.207	0.503
45	0.410	0.116	1.311	0.305	1.077	0.449
46	0.583	0.165	1.022	0.238	1.169	0.487
47	0.879	0.249	1.401	0.326	1.029	0.429
48	0.624	0.177	2.027	0.471	1.401	0.584

H = diversity J = evenness

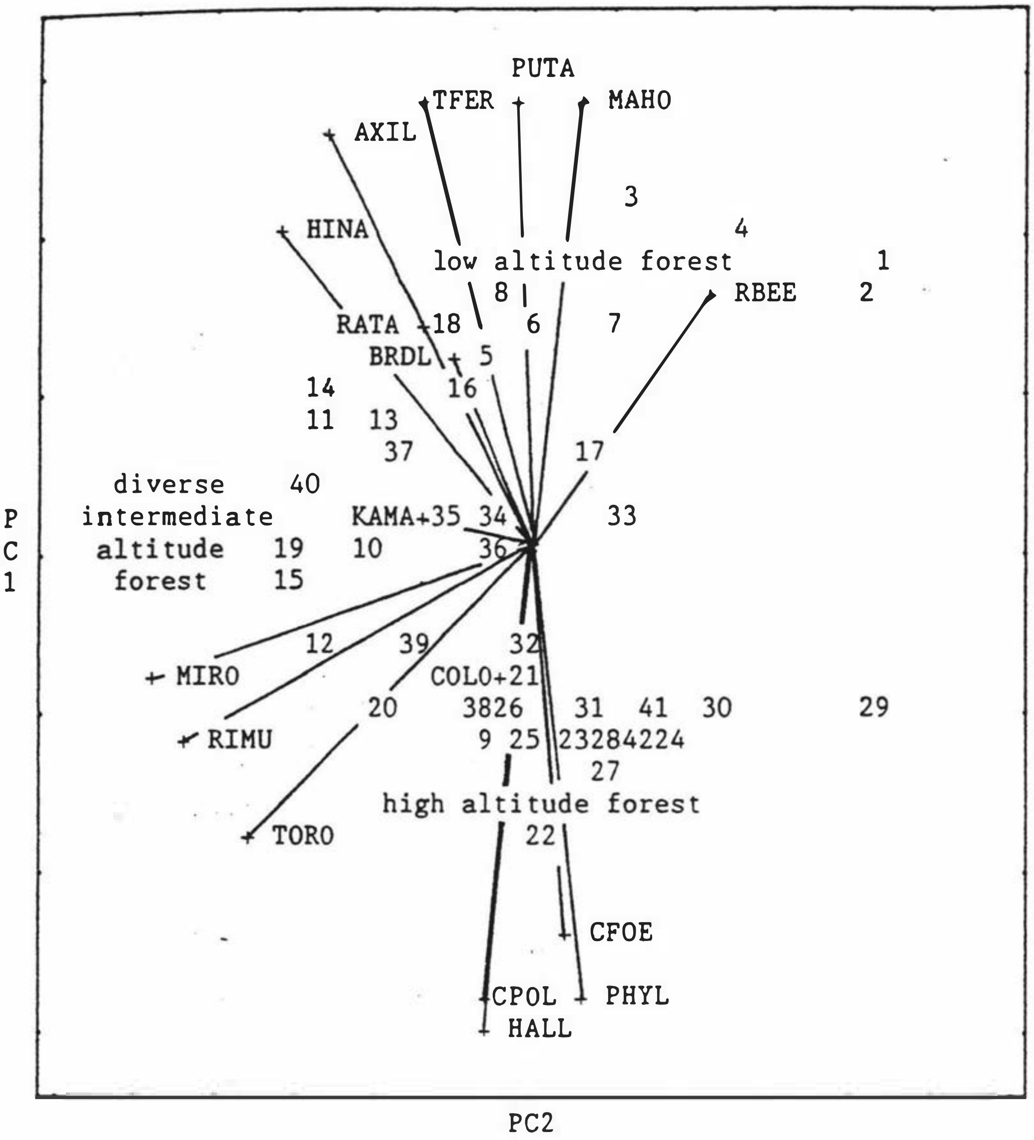

FIGURE 1.5

Principal component analysis of tree species distribution

(tiers data, stations 43-48 excluded)

The first two principal components explained 56.1% of the variation within the data set (PC1 = 40.7%, PC2 = 15.4%). Tree species abbreviations as in table 1.1, stations are numbered. Two of the 17 variables were skewed.

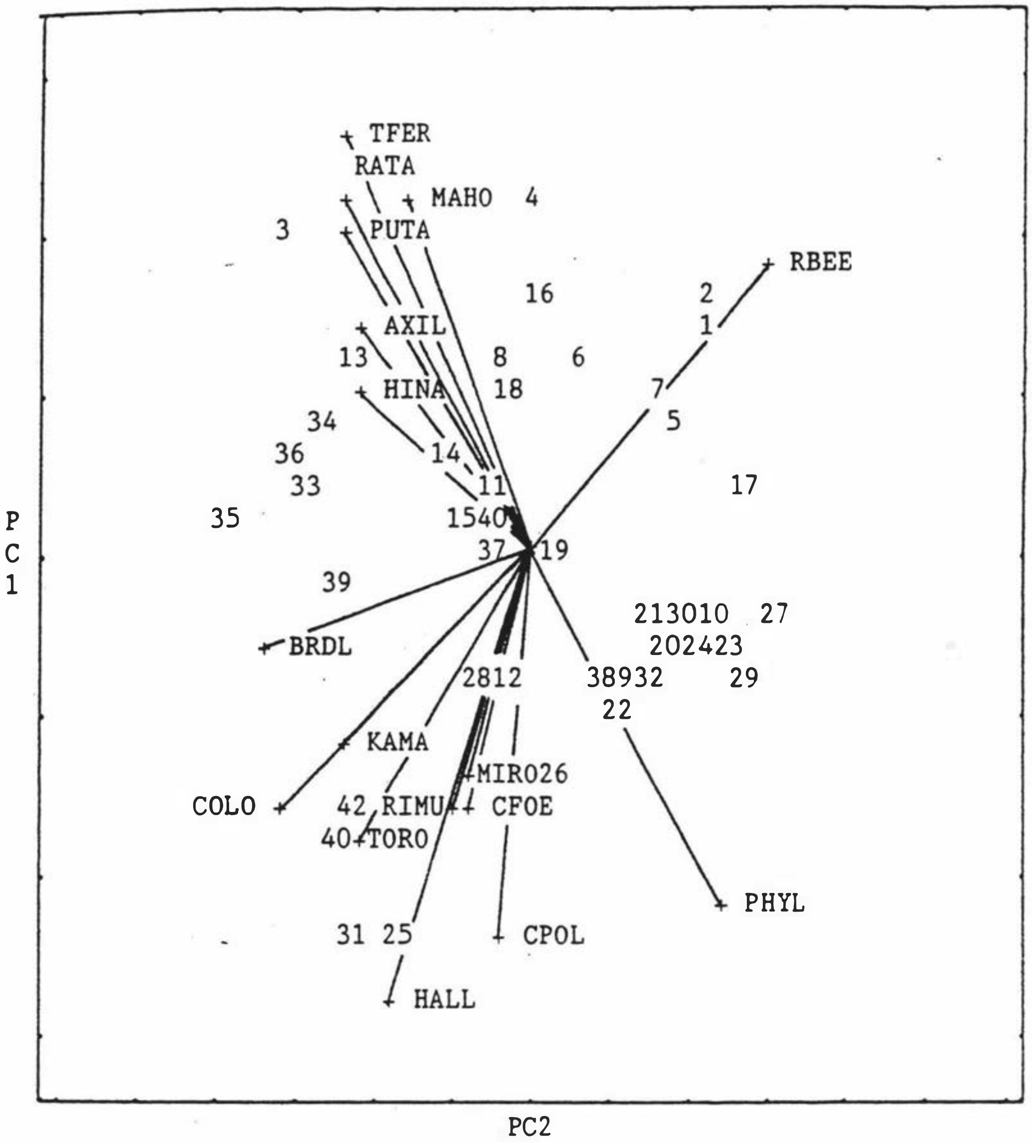

FIGURE 1.6

Principal component analysis of tree species distribution

(point height intercept data, stations 43-48 excluded)

The first two principal components explained 46.4% of the variation within the data set (PC1 = 31.5%, PC2 = 14.9%). Tree species abbreviations as in table 1.1, stations are numbered. 11 of the 17 variables were skewed.

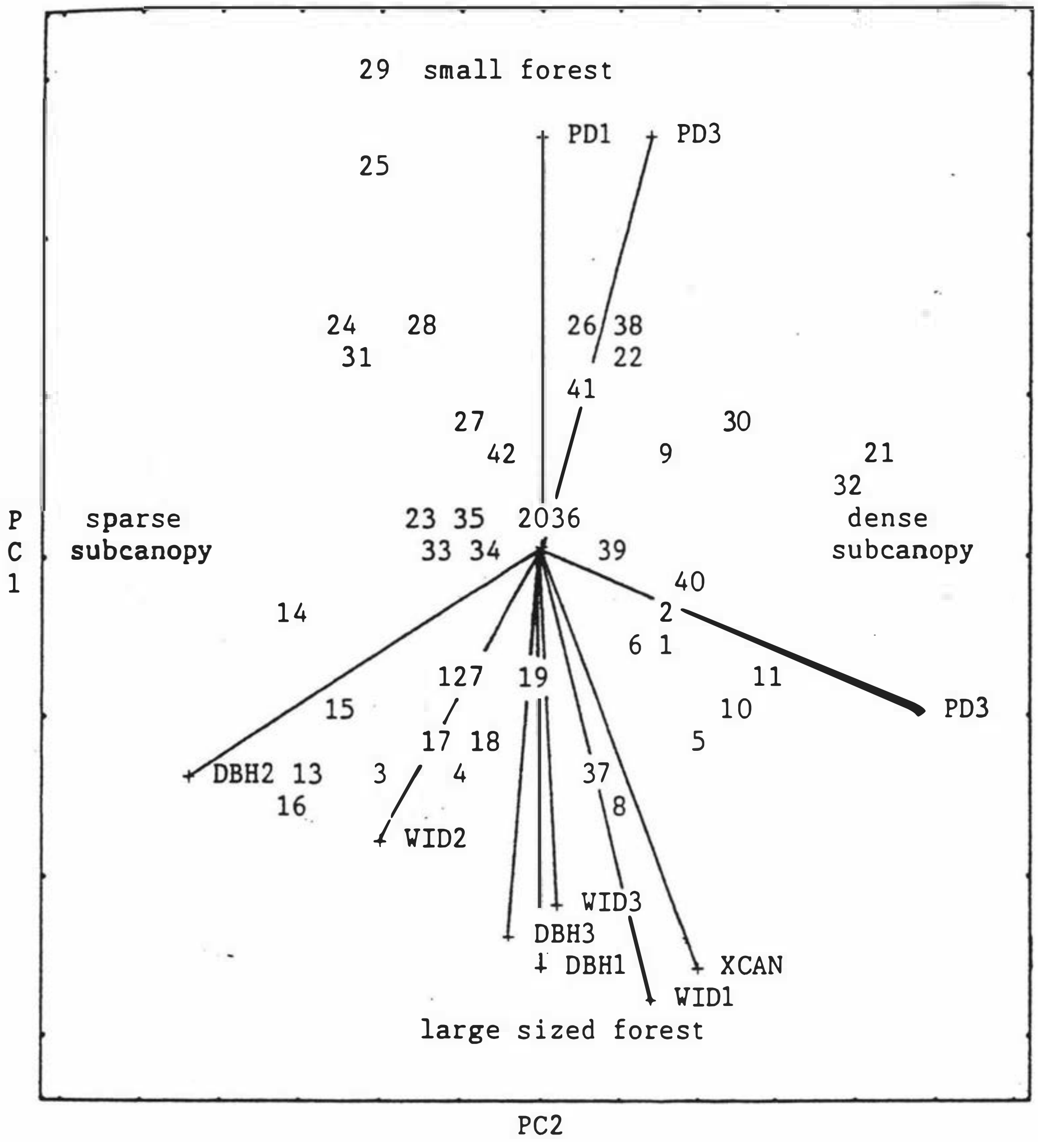

FIGURE 1.7

Principal component analysis of forest structure

(stations 1-42 only)

The first two principal components explained 64.3% of the variation within the data set (PC1 = 48.1%, PC2 = 16.3%). Structural parameter abbreviations as in appendix 3, stations are numbered. No variable was skewed.

FHD of the stations in the Mangatainoka River valley (stations 1-20) were significantly larger ($t_{40} = 7.67$, $p < 0.001$) than the other forest stations. PSD was calculated from the forest tiers data (Table 1.4), a total of 74 plant species was recorded. The four subalpine stations had lower PSD but no pattern was evident in the rest of the study area. FHD and PSD were not significantly correlated ($t_{46} = 0.64$), and when the subalpine stations were removed from the analysis ($t_{40} = 0.034$).

The inter-relationships between forest structure and the stations of the study area are displayed in figure 1.7 (data in Appendix 3). Because some of the tiers were absent or missing at the upper six stations these stations were excluded from the analysis. The first two principal components explained 64.4% of the variance in the data set. The first principal component differentiated stations mainly on the basis of tree size. The densities of both the canopy and the shrub layers were highly positively correlated with this component. These were negatively correlated with mean canopy height, mean foliage width of all three vegetational strata, and mean trunk diameter of both canopy and shrub layers. The second principal component separated stations on the basis of subcanopy density and mean trunk diameter of the subcanopy. These parameters were inversely correlated with each other.

The stations of transects one and two and the associated stations of transect three were correlated with large trees. All of these stations, with the exception of station nine, were negatively correlated with principal component one. The other stations were rrelated with smaller trees, the exception in this group was station

37. The density and size of the subcanopy varied markedly within transects.

Precipitation and temperature were measured at four sites in the study area:

- A At station 17 near the Mangatainoka forks at 360m.
- B At station 11 in the Mangatainoka valley at 580m.
- C At station 24 on the ridge at 730m.
- D At station 37 in the Ruapae valley at 580m.

Temperature was recorded using a maxima/minima thermometer at each site. An analysis of variance of the recorded temperatures indicated that site A was significantly warmer than the other stations (Table 1.5). Precipitation was recorded using 150mm capacity rain gauges. Initially one gauge was placed at each station but in the second year of the study an additional two gauges were placed at each site. Accurate measurement of total precipitation within the forest was difficult, what was actually measured was throughfall. The amount of water which reached each gauge was affected by the surrounding trees.The presence of three gauges at each site enabled the quantification of within-site variation and more accurate interpretation of differences between sites. Using these techniques it was found that stations B and D received significantly more throughfall than stations A and C (Table 1.6). On several occasions the rain gauges within the study area overflowed between visits hence the data from New Zealand Meteorological Station at Putara three kilometres from the study area were collected. The total monthly rainfall measured at Putara and the monthly maxima/minima temperatures at site C are displayed in figures 1.8 and 1.9. Temperature cycled annually, with maxima in summer and minima in winter. Rainfall did not vary in a predictable way.

TABLE 1.5

Mean temperatures within the study area

	SITE				
	A	B	C	D	S.E.D.
MEAN MAXIMUM (C)	15.4	14.6	14.4	14.5	0.13
MEAN MINIMUM (C)	4.8	3.7	3.6	3.9	0.09

S.E.D. = The standard error of the difference in temperature between sites on a weekly basis calculated by Analysis of Variance.

Applying Tukeys Test

A > B = C = D

Level of significance = 0.001 for both maximum and minimum temperatures.

TABLE 1.6

Mean rainfall within the study area

	SITE				
	A	B	C	D	S.E.D.
MEAN RAINFALL (cm) A	68.9	75.0	69.4	69.9	2.37
MEAN RAINFALL (cm) B	69.2	79.3	57.4	85.4	2.71

S.E.D. = The standard error of the difference in rainfall between sites on a weekly basis calculated by Analysis of Variance.

A = Visits 6 to 39 when there was one rain gauge at each site.

B = Visits 40 to 76 when there were three rain gauges at each site.

Applying Tukeys Test

Interval A = no significant differences between sites.

Interval B = Sites D = B > A > C

Site D > sites A and C at the 0.001 level of significance.
Site B > site C at the 0.001 level of significance.
Site B > site A at the 0.05 level of significance.
Site A > site C at the 0.05 level of significance.

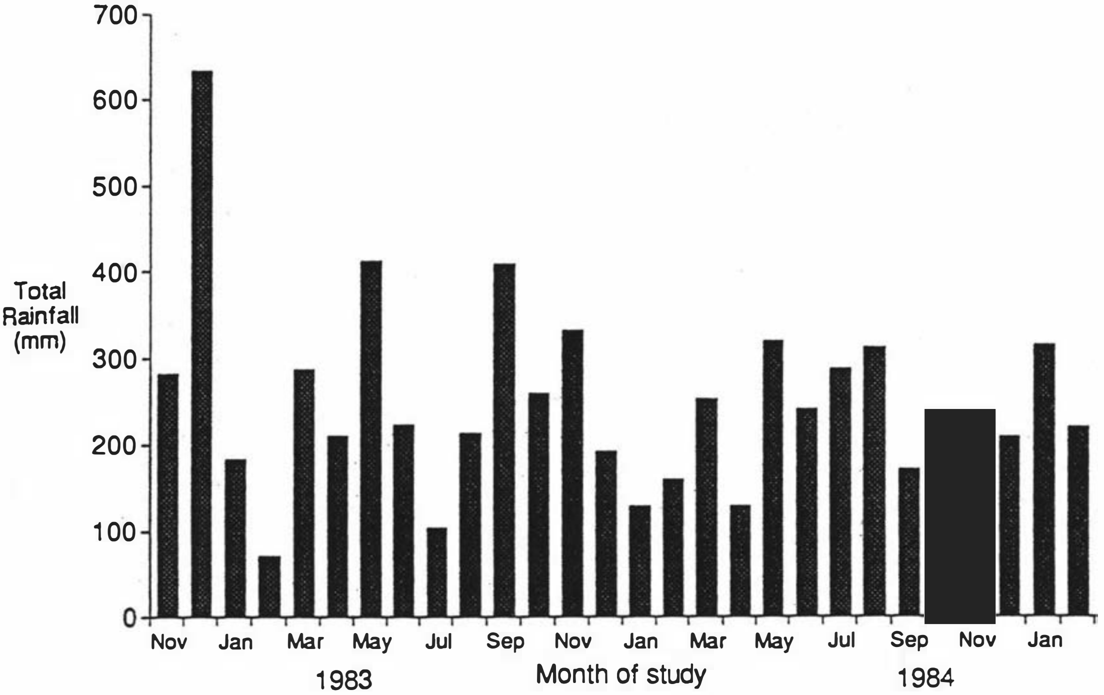

FIGURE 1.8
Total rainfall at Putara

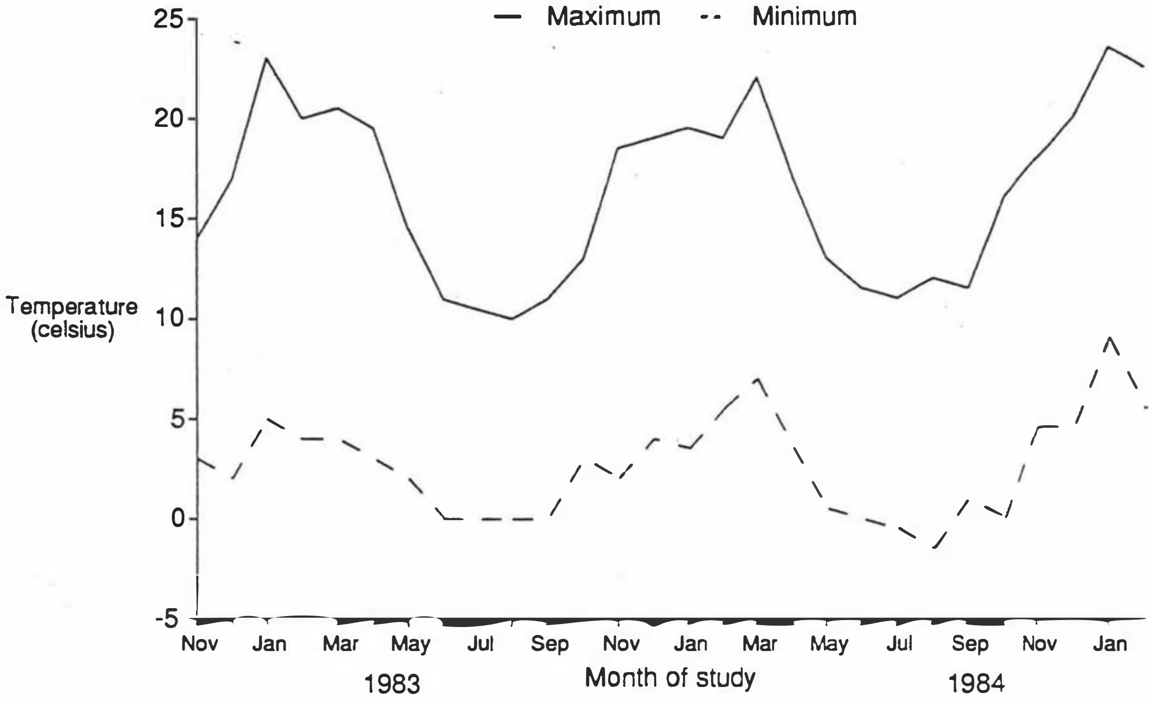

FIGURE 1.9
Monthly maxima and minima temperatures at site C

CHAPTER 2

BIRD ABUNDANCE AND DISTRIBUTION

2.1 Introduction

To establish the relative importance of determinants of bird species abundance and distribution a census technique which estimates either the relative or absolute abundance of those bird species must be selected. The validity of density estimates and the ultimate accuracy of the different types of land bird survey are the subject of debate (Ralph and Scott 1981). There have been several comparative studies of the various census techniques by simultaneous collection of data using two or more methods (Franzreb 1976, 1981, Emlen 1977, Desante 1981, Edwards et al. 1981, Anderson and Ohmart 1981, O'Meara 1981, Redmond et al. 1981, Tilghman and Rusch 1981, Svensson 1981, Arnold 1983, Hamel 1984, Shields and Recher 1984, Verner and Ritter 1985, 1988). The general conclusion to be drawn from these papers is that the most accurate method of estimating density is banding and study of all birds in an area. All of the other techniques underestimate population density. In decreasing accuracy the other methods were spot mapping, circular-plot, and line transect (van Riper 1981). Dawson (1981c) argued that all of these techniques have problems and none provide accurate estimates of absolute abundance. He concluded that the most efficient type of survey given the possible sources of error was a line transect technique with a near/far ratio (Jarvinen and Vaisanen 1975).

Verner (1981) states that: "bird counting is a distressingly imprecise science", and points to the high variance between counts as an indication of the large number of biasing factors. He concluded that, whilst improved sampling design could reduce the amount of bias, it had proved impossible to count accurately all species comprising avian communities thus far sampled.

In New Zealand forests far more birds are heard than seen and this precludes accurate estimates of distance (Dawson and Bull 1975). Additionally, the ruggedness of the terrain in many New Zealand forests makes the use of transect censuses difficult because the observer must concentrate on progressing through the forest. These difficulties led Dawson and Bull (1975) to develop a cost efficient method for use in New Zealand forests. The method involves the recording of every bird seen or heard in a stationary count over a five-minute period. Transects through particular habitats can be undertaken with count stations at sufficient intervals to avoid overlap of census areas. The technique was developed to provide an index of abundance which could detect major differences in the density of common bird species between areas. It cannot be used in comparing the density of the same species at different times of the year or for inter-species comparisons. This is because no estimation of detection distances is included, hence differences in conspicuousness could account for most of the variability between species or seasons.

Several researchers in New Zealand have used five-minute bird counts to compare bird communities in different habitats (Wilkinson and Guest 1977, Dawson et al. 1978, Onley 1980, Gill 1980, Harrison and Saunders

1981, Wilson et al. 1988). Gill (1980) has shown that counts for 2 species varied in conjunction with density assessed by territorial mapping. However, there was concern about variation in the sound characteristics of different habitats. Wiley and Richards (1982) reviewed the factors that affect sound transmission; they concluded that quantification of sound attenuation in different habitats needed repeated measurements at different locations, heights above ground, distances, times of day, and weather conditions. In New Zealand Harrison and Saunders (1981) attempted to quantify variation in sound attenuation. The differences between habitats were inconsistent and variable. Amplification, i.e. an increase in volume with increased distance, occurred at various distances, frequencies and areas. They concluded that the resolution of factors affecting sound attenuation in forests would be an extremely complex task.

To compare FHD and PSD with BSD, and to use PCA to describe the relationship of bird community structure to forest structure and composition, estimates of the density of each bird species at each station are required. I calculated an index of conspicuousness by the inclusion of a distance delimiter. The relative conspicuousness combined with the total count yielded an index of abundance. The census was then equivalent to the transect count method of Jarvinen and Vaisanen (1975) modified for point counts. Because a near/far ratio quantifies conspicuousness it can be used as a summation of bias. This allows valid comparisons of different species in varied habitats at different times of the year. However, if the number of near or far counts is small large errors can result due to chance. This type of bias is primarily caused by small numbers of counts but can also occur because a species is inconspicuous or rare.

The modification of the standard five-minute bird count to include an interior area close to the researcher is easily applied. However, the modification is of major significance because it transforms the five-minute bird count from a coarse index of abundance with severe limitations to a census technique. As a result many more comparisons, both between habitats and species, can be made. The subsequent determination of those factors which are most important in structuring the bird community is facilitated.

In this chapter eight main points are considered:

1. The general effect of wind and water noise on the numbers of birds observed.
2. The use of near/far ratios to calculate an effective radius of detection for each bird species at each group of stations. Examination of the mean rank of these effective radii indicates which environmental variable has the largest effect on bird counts.
3. The use of near/far ratios in conjunction with total number of birds counted to calculate density indices. The density indices were compared with total bird counts and with density estimates based on near observations only.
4. The inter-relationships of bird species distributions with tree species distributions and forest structure.
5. The total numbers of each bird species observed in each month of the study.
6. The relationship of changes in numbers of birds observed to changes in conspicuousness and estimates of changes in density on a monthly

basis.

7. Similarity of bird species distributions within the study area between years.
8. Seasonal movement of birds within the study area.

2.2 Methods

Forty-eight bird counting stations on six transects were established (Fig. 1.1). From September 1982 until February 1985 modified five-minute bird counts (Dawson and Bull 1975) were executed at each station. The modification consisted of recording each bird observed as near or far. Near observations were within 20m horizontally of the observer; all other observations were far. Bias due to time of day was eliminated by making three counts per month at each station; morning, middle of day and afternoon. No counts were made within 2 hours of dawn or dusk. Bias due to differential weather conditions was reduced by avoiding adverse weather conditions. The near/far ratio was used to derive indices of relative abundance. The index was based upon the linear model of Jarvinen and Vaisanen (1975) modified for point counts (Appendix 4). To calculate the index of abundance at each station the stations were grouped.

Group 1 = Stations 1-8, 17,18 = Transect one and related stations
Group 2 = Stations 9-16, 19,20 = Transect two and related stations
Group 3 = Stations 21-32, 41-42 = Forest stations of the ridge
Group 4 = Stations 33-40 = Transect three
Group 5 = Stations 43-48 = Subalpine and scrub stations

This minimized stochastic effects on the near/far ratio. Radii of detection were estimated for each of these groups. The relative density per station was computed from the total numbers of birds observed at that station and the effective radius at that group of stations. The accuracy of the method was checked by comparing the densities obtained with estimates based on the number of near birds observed. When density was calculated on near observations only it was assumed that all birds within 20m of the observer were recorded. However, this calculation would be an underestimate of population density because some birds would be missed.

Data recorded in each count:

1. The count station.
2. New Zealand Standard Time at the start of the count.
3. The wind noise on a subjective scale
    0 = calm
    1 = some leaf movement no noise heard
    2 = distant rustle
    3 = immediate noise, twigs and small branches moving
    4 = immediate noise with gusts, branches moving
    5 = continuous high wind
    6 = gale, leaves being stripped off trees
4. Cloud cover in octas.
5. The water noise on a subjective scale
    1 = no water noise
    2 = low level water noise
    3 = medium level water noise
    4 = high level water noise

6. The numbers of each bird species observed.

To quantify environmental noise on an objective scale a Bruel and Kjaer precision sound level meter type 2206 was used on three field trips.

2.3 Results

Quantification of environmental noise

Bird counts at different stations in my study area were biased by environmental variables. Some of the lower altitude stations, particularly those on transect one, were close to streams which produced background water noise . The upper stations were more exposed to wind and the related background noise. The counts at stations 43 through 48 were further biased because the observer could see over the top of the canopy and sound was not impeded by intervening vegetation.

The mean decibel counts for different levels of background noise are displayed in table 2.1. The decibel meter did not measure noise of less than 30 decibels, but only the lowest category of noise was in this range. The total number of birds observed decreased with increasing wind noise (Fig. 2.1). Wind noise of three or greater significantly affected the number of birds observed (Tukeys one way analysis of variance alpha < 0.05).

The effect of water noise on count efficiency was difficult to evaluate. The low altitude transects had high densities of birds but were also nearest to the streams. Consequently more birds were observed at low and intermediate levels of water noise than when no water noise was heard (Fig. 2.2). Water noise levels of four were regularly recorded at station 17 which was within 20 metres of the Mangatainoka Stream, this level of noise was only recorded at other stations when the streams were in flood. Wind noise affected count efficiency more than water noise (Fig. 2.3). Additionally, forest structure and topography influence sound attenuation and thus bird counts.

Bird distribution and abundance

Eighty modified five-minute bird counts were conducted in the study area. The total number of observations of each species, scientific names, common names and abbreviations used in subsequent figures and tables are displayed in table 2.2 (total numbers of birds observed at each station in Appendix 5, proportions near/far in Appendix 17). Twenty-nine bird species were observed in the study area. Eight of these species were not resident within the study area (Table 2.2).

TABLE 2.1

Quantification of environmental noise

Water Noise	Wind Noise	Mean Decibels	Standard Deviation	Number of Observations
0	1	<30.00	**	6
0	2	31.43	0.63	20
0	3	33.89	0.93	9
0	4	42.07	4.45	14
0	5	53.00	4.00	3
0	6	60.00	**	1
1	2	31.00	0.00	3
1	3	32.00	**	1
2	2	33.31	0.95	13
2	3	35.21	2.29	14
2	4	40.27	4.69	11
2	5	51.00	1.41	2
3	1	36.83	0.29	3
3	2	41.32	3.87	11
3	3	46.17	4.15	18
3	4	46.53	2.83	15
4	2	53.00	**	1
4	4	62.00	**	1

** = standard deviation not calculable

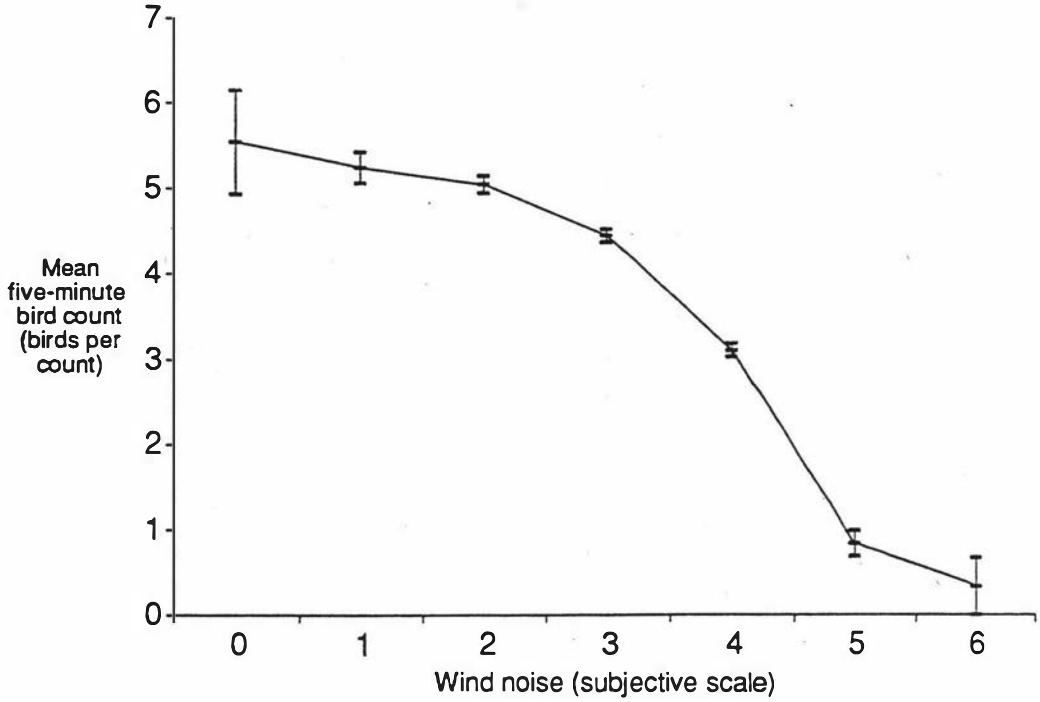

FIGURE 2.1
Effects of wind noise on mean five-minute bird counts

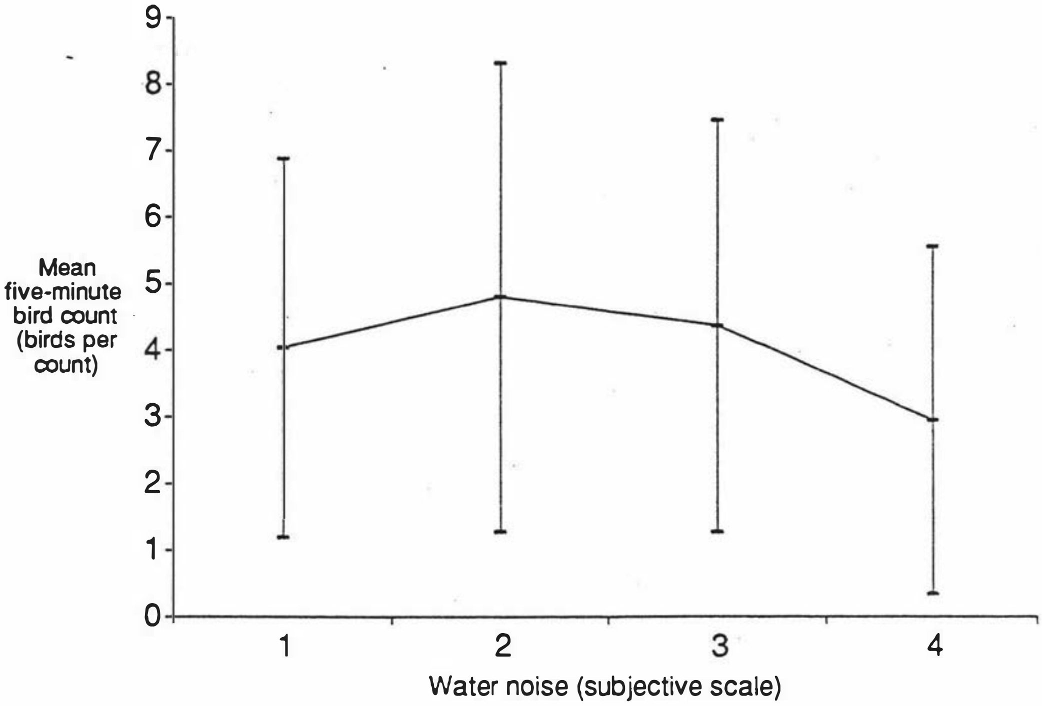

FIGURE 2.2
Effects of water noise on mean five-minute bird count

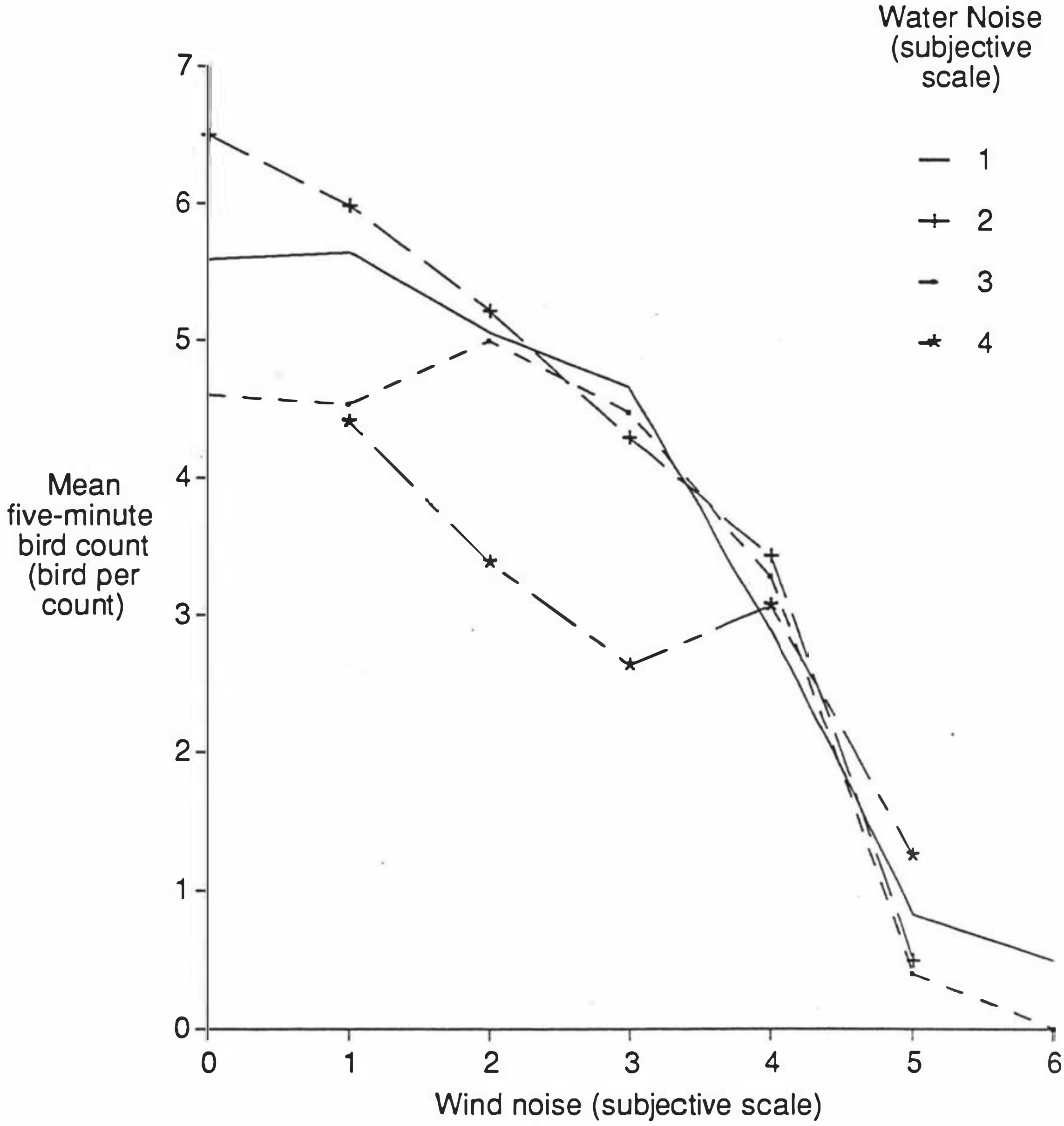

FIGURE 2.3
Effects of wind and water noise
on mean five-minute bird counts

TABLE 2.2
Total numbers of birds observed in five-minute bird counts for all species observed in the study area

Scientific Name	Common Name	Code	Count	
Tadorna variegata	Paradise Shelduck	SHEL	2	R
Circus approximans	Australasian Harrier	HARR	0	
Larus dominicanus	Dominican Gull	GULL	3	
Hemiphaga novaeseelandiae	New Zealand Pigeon	PIGE	122	R
Falco novaeseelandiae	New Zealand Falcon	FALC	32	R
Cyanoramphus auriceps	Yellow-Crowned Parakeet	PARA	78	R
Platycercus eximius	Eastern Rosella	ROSE	1	
Kakatoe galerita	Sulphur-Crested Cockatoo	COCK	0	
Chalcites lucidus	Shining Cuckoo	SHIN	63	R
Eudynamis taitensis	Long-Tailed Cuckoo	LTCU	49	R
Ninox novaeseelandiae	Morepork	MORE	0	R
Halcyon sancta	New Zealand Kingfisher	KING	26	R
Acanthisetta chloris	Rifleman	RIFL	1383	R
Rhipidura fuliginosa	Fantail	FANT	856	R
Petroica macrocephala	Tomtit	TOMT	2179	R
Mohoua albicella	Whitehead	WHIT	3380	R
Gerygone igata	Grey Warbler	WARB	2994	R
Turdus merula	Blackbird	BLAC	755	R
Turdus philomelos	Thrush	THRU	27	R
Prunella modularis	Dunnock (Hedge Sparrow)	DUNN	190	R
Anthus novaeseelandiae	New Zealand Pipit	PIPI	20	R
Anthornis melanura	Bellbird	BELL	775	R
Prosthemadera novaeseelandiae	Tui	TUI	158	R
Zosterops lateralis	Silvereye	SILV	2853	R
Chloris chloris	Greenfinch	GREE	4	
Carduelis carduelis	Goldfinch	GOLD	9	
Fringilla coelebs	Chaffinch	CHAF	646	R
Emberiza citrinella	Yellowhammer	YELL	0	
Gymnorhina tibicen	Australian Magpie	MAGP	38	

Species which were observed in the study area but not during a five minute bird count are included, they have a count of zero.

R = Signifies a resident breeding species.

Magpies were the most frequently observed visitors. Magpies occasionally flew in from the surrounding farmland and sang conspicuously from the top of large trees. Of the twenty-one resident species only eleven were seen in sufficient numbers in the forested part of the study area for the density index to be applied. Direct observations of some of the rarer resident species allowed me to ascertain further information.

One pair of paradise shelduck bred successfully in the Mangatainoka River each year. It may have been the same pair each year. They ranged from station 5 out to the surrounding farmland. One pair of falcons were occasionally present within the study area. In the summer of 1983/84 they nested in the crown of a large rimu tree approximately 250 metres southeast of station 19. No chicks were observed and they did not nest within the study area in the previous or subsequent years. Low numbers of dunnocks, pipits, shining cuckoos, long-tailed cuckoos, parakeets, thrushes and kingfishers were observed. Of the eleven common bird species mean density indices ranged from an estimate of 4.9 birds per hectare for riflemen to 0.03 birds per hectare for tuis.

Variability in detection between habitats

In my study area differences in detectability were observed between habitats (Table 2.3). These differences were largest between forest habitat and subalpine scrub but were also important between forest habitats. Inconspicuous species, such as rifleman, varied little in conspicuousness between habitats indicating that unmodified five-minute

TABLE 2.3

Mean five-minute bird counts, bird density indices and effective radii sampled by station group

Mean five-minute bird counts

Species: Station group	WARB	WHIT	FANT	SILV	CHAF	RIFL	TOMT	BELL	TUI	PIGE
1	.852	.521	.739	1.198	.197	.280	.535	.135	.015	.004
2	1.067	1.699	.225	.955	.209	.584	.720	.294	.088	.124
3	.674	1.033	.038	.474	.125	.312	.625	.161	.032	.014
4	.823	.597	.066	.450	.164	.533	.547	.255	.028	.005
5	.367	.135	.135	.650	.158	.004	.260	.185	.046	.002

	BLAC	DUNN	SHIN	PIPI	LTCU	FALC	MAGP	PARA	THRU	KING
1	.116	.003	.021	.000	.012	.001	.010	.001	.010	.030
2	.175	.001	.029	.000	.019	.014	.005	.055	.011	.001
3	.197	.013	.013	.000	.013	.005	.006	.025	.002	.000
4	.198	.006	.006	.000	.011	.002	.025	.005	.012	.002
5	.363	.350	.008	.042	.004	.027	.006	.004	.000	.000

Effective radii sampled (metres)

Species: Station group	WARB	WHIT	FANT	SILV	CHAF	RIFL	TOMT	BELL	TUI	PIGE
1	36.1	34.4	30.5	35.2	62.6	15.4	46.0	87.9	44.4	*
2	50.7	43.8	32.8	47.2	122.6	15.5	43.2	96.8	58.7	16.6
3	49.9	51.7	36.8	47.6	70.1	15.3	46.4	60.5	55.4	17.1
4	42.8	54.4	31.2	62.0	78.8	14.9	46.4	139.6	80.0	*
5	125.8	*	*	50.6	117.0	*	74.3	176.8	*	*

	BLAC	DUNN	SHIN	PIPI	LTCU	FALC	MAGP	PARA	THRU	KING
1	39.6	*	32.1	*	*	*	*	*	*	*
2	74.1	*	*	*	*	*	*	*	37.8	*
3	93.8	72.7	50.2	*	*	*	*	100.3	*	*
4	150.6	*	*	*	*	*	*	*	*	*
5	111.9	60.2	*	40.1	*	67.4	29.8	*	*	*

* = effective radius sampled not calculable.
Bird species scientific names in table 2.2

TABLE 2.3 continued

Density indices (birds per hectare)

Species: Station group	WARB	WHIT	FANT	SILV	CHAF	RIFL	TOMT	BELL	TUI	PIGE
1	2.08	1.40	2.52	3.08	.16	3.76	.81	.06	.02	**
2	1.32	2.82	.66	1.36	.04	7.76	1.23	.10	.08	1.43
3	.86	1.23	.09	.67	.08	4.26	.93	.14	.03	.15
4	1.43	.64	.22	.37	.08	7.60	.81	.04	.01	**
5	.07	*	0.00	.81	.04	*	.15	.02	*	**

	BLAC	DUNN	SHIN	PIPI	LTCU	FALC	MAGP	PARA	THRU	KING
1	.24	*	.07	0.00	*	*	*	*	*	*
2	.10	*	*	0.00	*	*	*	*	.03	*
3	.07	.01	.02	0.00	*	*	*	.01	*	0.00
4	.03	*	*	0.00	*	*	*	*	*	*
5	.09	.31	*	.08	*	.02	.02	*	0.00	0.00

* = no near birds observed.   ** = no far birds observed

Density per hectare (based on near observations only)

Species: Station group	WARB	WHIT	FANT	SILV	CHAF	RIFL	TOMT	BELL	TUI	PIGE
1	1.63	1.08	1.88	2.40	.14	1.88	.67	.05	.02	.03
2	1.11	2.31	.51	1.13	.04	3.90	1.00	.09	.07	.77
3	.72	1.04	.07	.55	.07	2.11	.77	.12	.03	.09
4	1.17	.55	.16	.32	.07	3.68	.67	.04	.01	.04
5	.07	.00	.00	.68	.03	.00	.13	.02	.00	.02

	BLAC	DUNN	SHIN	PIPI	LTCU	FALC	MAGP	PARA	THRU	KING
1	.19	.00	.05	.00	.00	.00	.00	.00	.00	.00
2	.09	.00	.00	.00	.00	.00	.00	.00	.02	.00
3	.06	.01	.01	.00	.00	.00	.00	.01	.00	.00
4	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00
5	.08	.27	.00	.07	.00	.02	.02	.00	.00	.00

Mean rank effective radius sampled per station group
(spp 1-11 excluding PIGE)

1 = 1.2   2 = 2.8   3 = 2.65   4 = 3.65   5 = 4.5

Group 1 = Stations 1-8, 17,18 = Transect one and related stations
Group 2 = Stations 9-16, 19,20 = Transect two and related stations
Group 3 = Stations 21-32, 41-42 = Forest stations of the ridge
Group 4 = Stations 33-40 = Transect three
Group 5 = Stations 43-48 = Subalpine and scrub stations

bird counts can be used as an index of abundance for this species (Table 2.3). The detection of conspicuous species varied between forest habitats. For these species five-minute bird counts should not be used as indices of abundance. For example, the five-minute bird counts of warblers indicated that they were most abundant on transect two, but analysis of the near/far ratio of observations indicated that they were actually more abundant on transect one where they were less conspicuous (Table 2.3).

Most species were least detectable on transect one. These stations were at the bottom of the Mangatainoka valley close to the river in dense, high-canopy forest all of which combined to diminish the number of far observations. Transect two and the stations of the ridge had similar effective radii of detection for most species. Transect two was in high-canopy, relatively sheltered forest, whereas the stations of the ridge were in low-canopy forest but were more exposed to wind and the associated noise. Transect five was in forest of similar canopy height to that of the ridge stations, but was sheltered from the wind. Transect five was subject to considerable water noise from the Ruapae Stream, but despite this noise many far observations were recorded. This was particularly evident for the most conspicuous species, bellbird, tui, and blackbird, which were often heard calling on the other side of the valley. Transect six was exposed to wind noise, but this was compensated for by the low canopy. Most observations on this transect were of distant birds.

Height of the canopy was apparently the major factor affecting bird counts.

Bird/habitat inter-relationships

The four subalpine stations (45-48) differed from the rest of the study area. The mean canopy height was one metre or less. Because subcanopy and shrub layers were defined as greater than 0.5 metres but under the canopy these layers were missing at the subalpine stations. Stations 43 and 44 were intermediate in vegetation structure and composition between the subalpine stations and the forest stations of the ridge. Stations 43-48 were dominated by leatherwood and Dracophyllum. Pipits and dunnocks were observed at these stations but only rarely elsewhere. The common forest birds, with the exception of silvereyes, were rare or absent at these stations. The differences between these stations and the forest stations of the rest of the study area obscured relationships within the forest in preliminary analyses.

The relationship of bird species distribution to vegetation and habitat was initially investigated using diversity indices. At the 42 forest stations BSD was significantly correlated with FHD ($r = 0.36$, d.f. = 40, $p = 0.018$), but BSD and PSD was not significantly correlated ($r = 0.30$, d.f. = 40, $p = 0.055$). The correlations of bird species densities with environmental variables were calculated individually (Appendix 7). The individual variables were not independent and the variation of the bird species distributions are difficult to interpret from a table such as that in appendix 7. To clarify these relationships the Pearson correlation coefficients of bird species densities with the principal component scores of the vegetative features of the 42 forest stations were calculated (Figs. 2.4, 2.5, 2.6).

When the subalpine scrub stations were excluded, the study area could be divided into three groups along an altitudinal continuum (Fig. 2.4). Low altitude, red beech dominated, high-canopy forest, in the Mangatainoka valley was associated with high densities of warblers, blackbirds, fantails, silvereyes and chaffinches (Figs. 2.4, 2.5, 2.6). Intermediate altitude, diverse, high-canopy forest was associated with high densities of whiteheads, tomtits, pigeons, tuis and riflemen (Figs. 2.4, 2.5, 2.6). Fewer birds were present in the high altitude, low-canopy forest. The only birds associated with this forest were bellbirds. Intermediate densities of riflemen and chaffinches and lower densities of the other common forest birds were observed.

Monthly variation in numbers of birds observed

The mean monthly five-minute bird counts are displayed in figure 2.7 (data in Appendix 8). Many species show a cyclical variation in numbers observed. In figure 2.8 the month/species inter-relationships are presented on one graph. There were two major patterns to the numbers of birds observed. Blackbirds, chaffinches, shining cuckoos, dunnocks, whiteheads, tomtits and kingfishers were observed in greatest numbers from October to January. Pipits and long-tailed cuckoos were

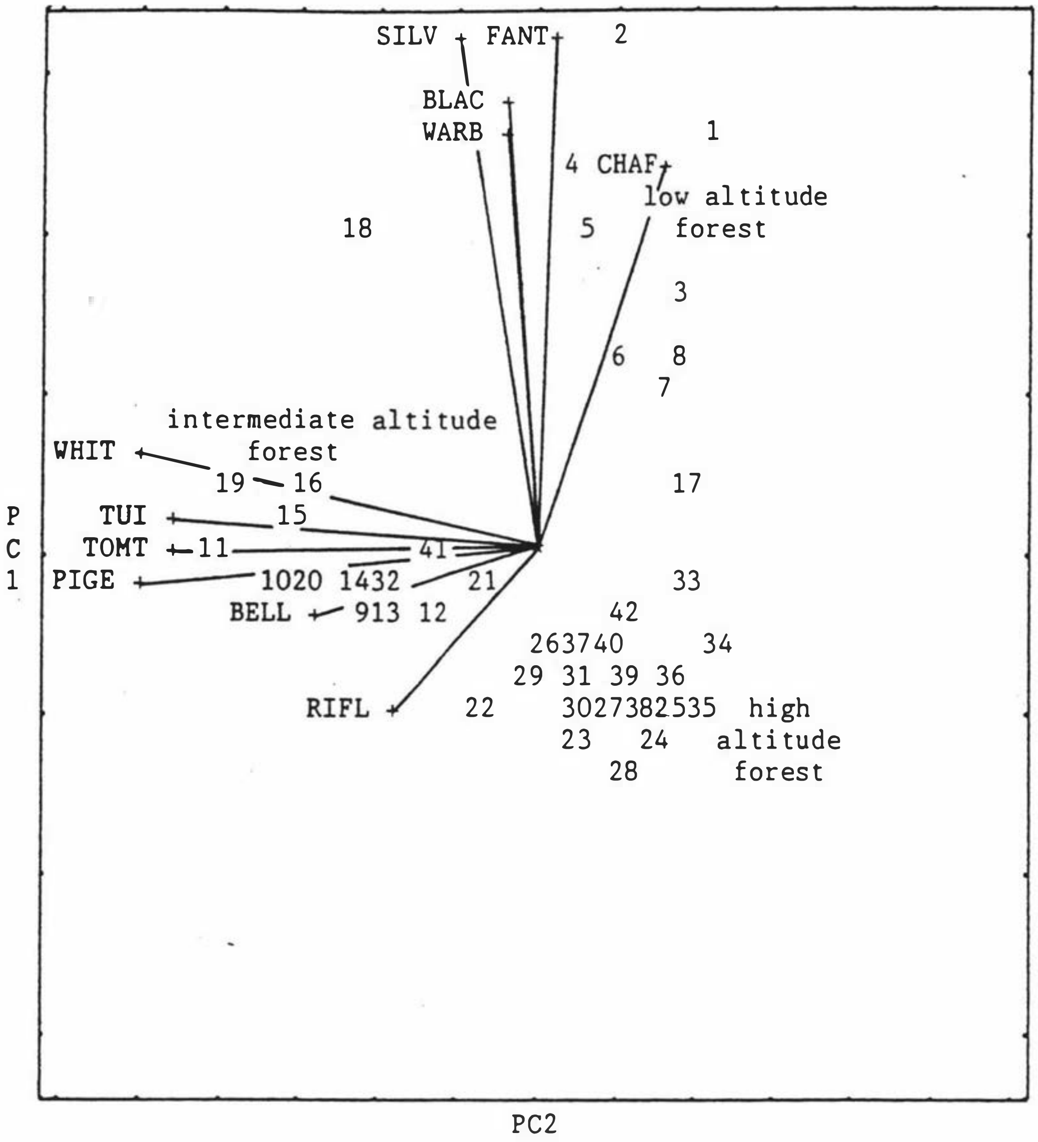

FIGURE 2.4

Principal component analysis of bird species distribution

(stations 1-42 only)

The first two principal components explained 64.3% of the variation within the data set (PC1 = 34.4%, PC2 = 29.9%). Bird species abbreviations as in table 2.2, stations are numbered. Three of the 11 variables were skewed.

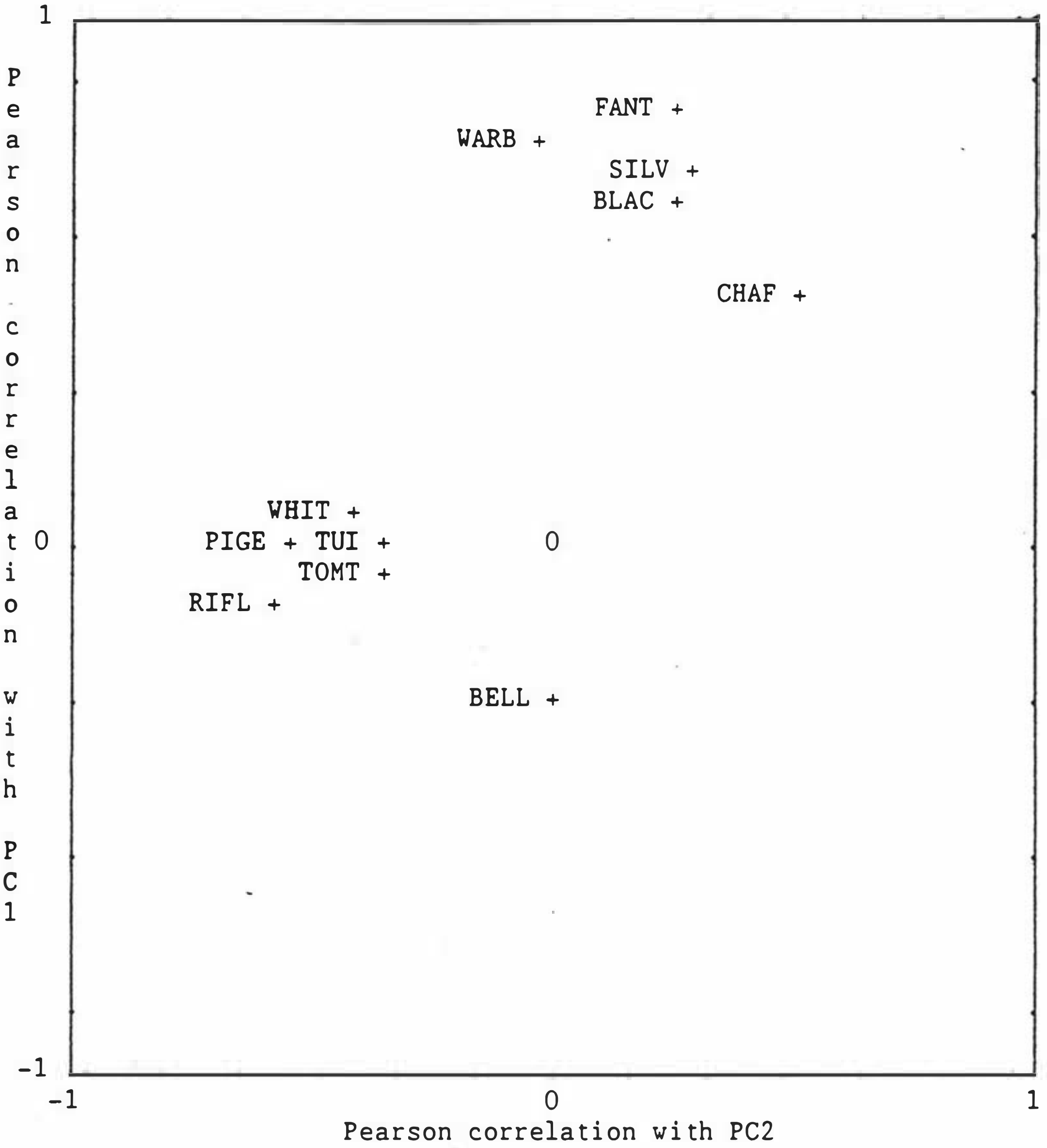

FIGURE 2.5

Bird species distributions
relationships to plant species distributions

The pearson correlation coefficients of bird species densities with principal component factor scores derived from analysis of the plant species distributions (Fig. 1.5).

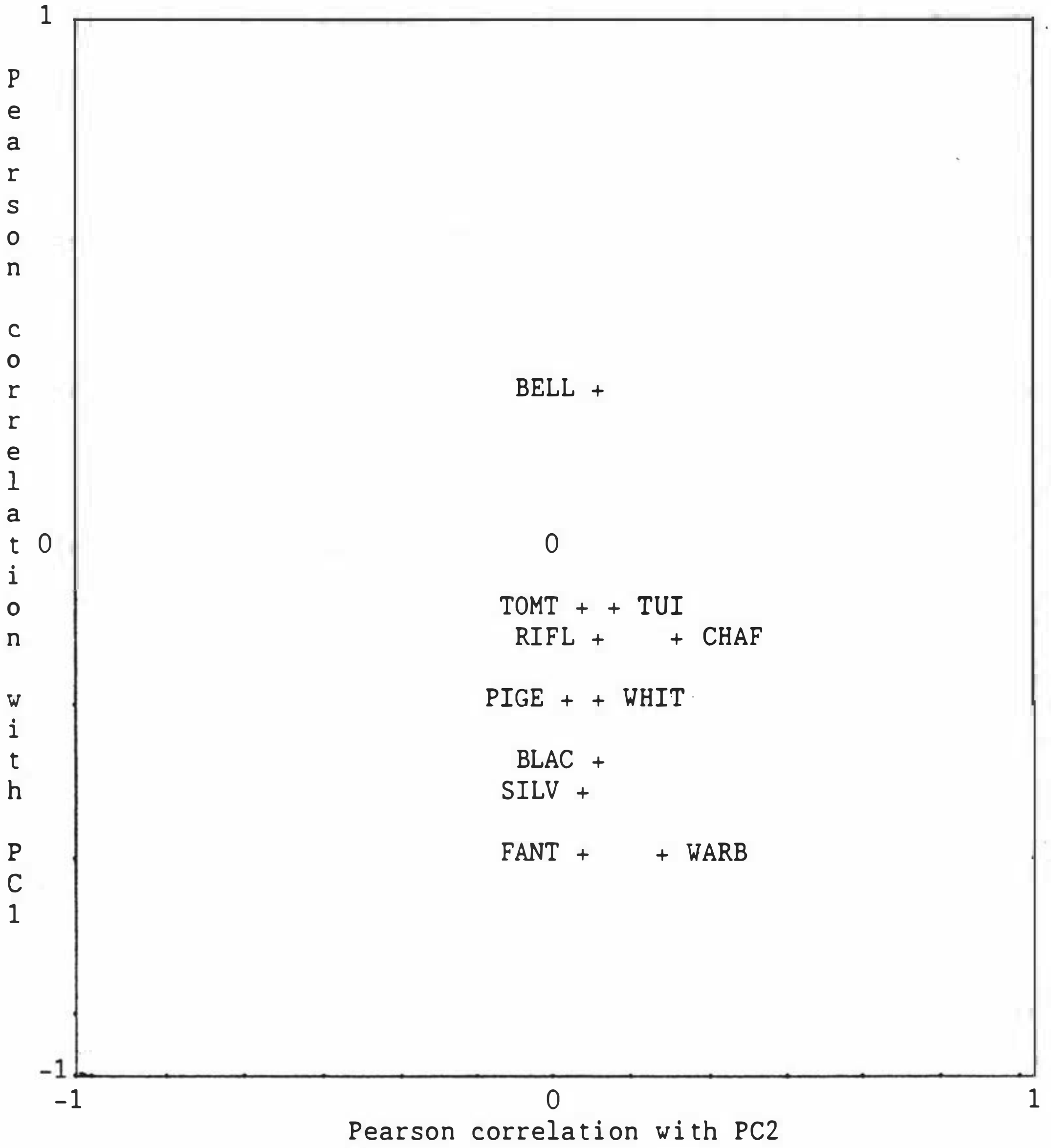

FIGURE 2.6

Bird species distributions relationships to forest structure

The Pearson correlation coefficients of bird species densities with principal component factor scores derived from analysis of the forest structure (Fig. 1.7).

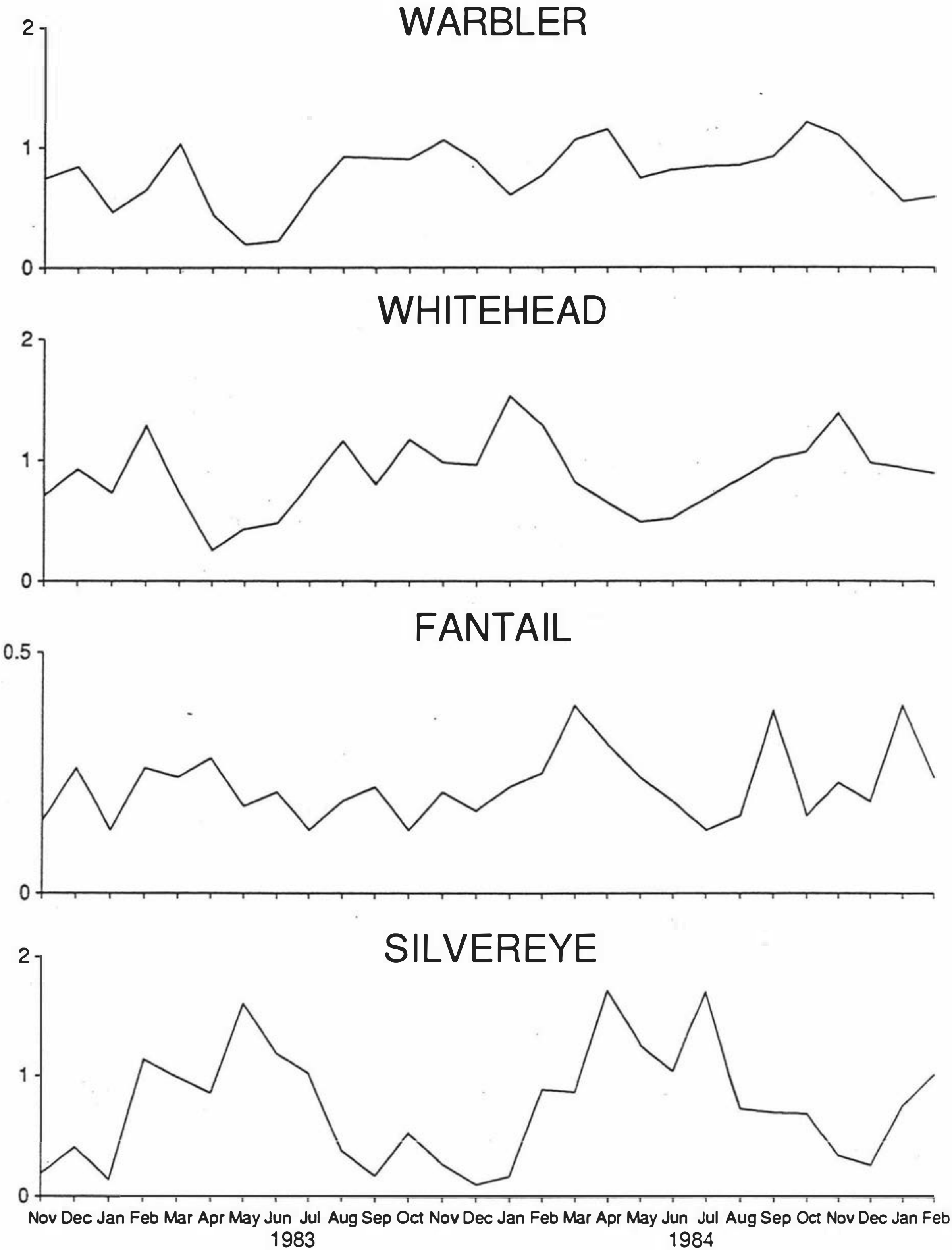

FIGURE 2.7: Mean monthly five-minute bird counts

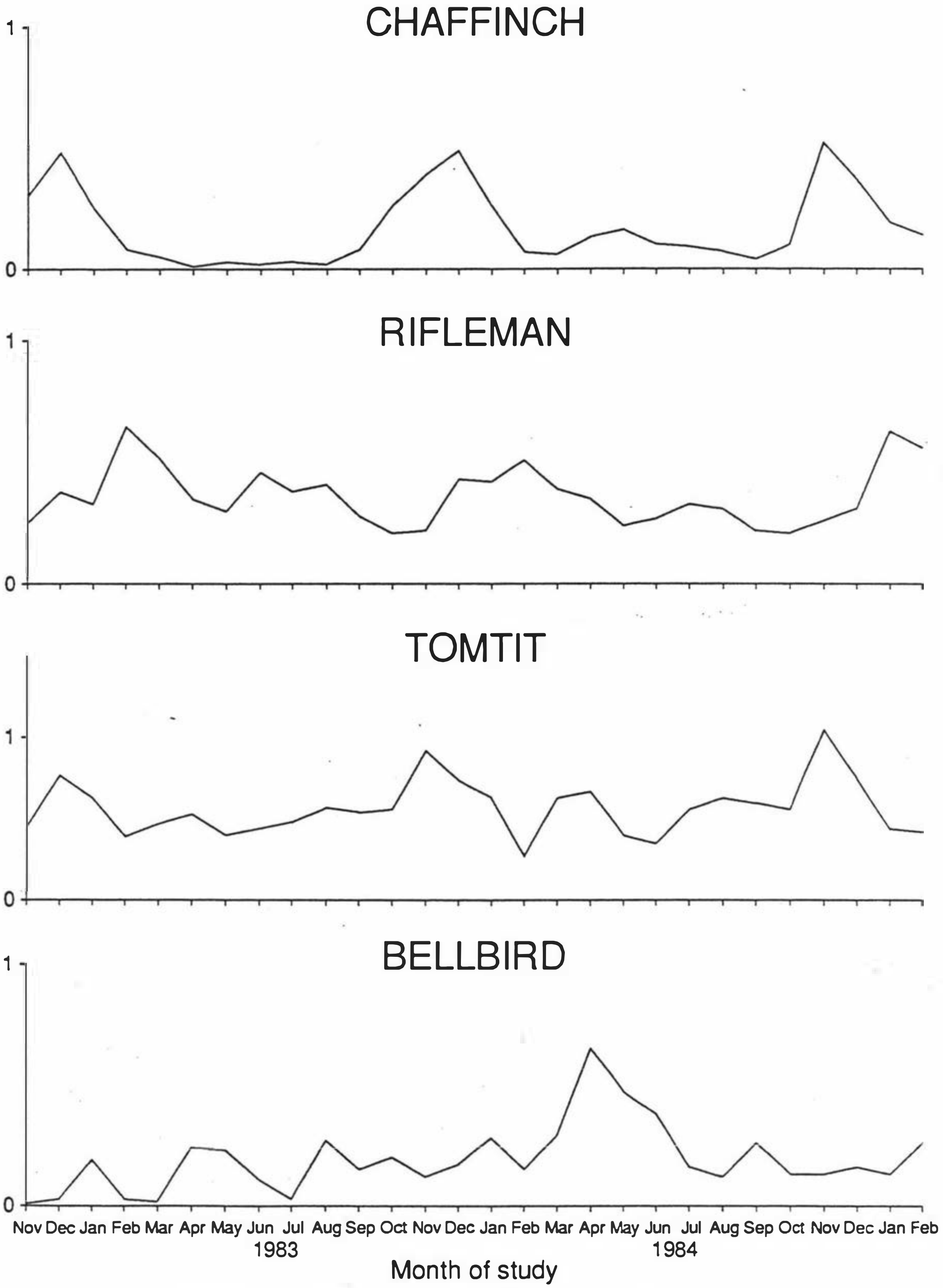

FIGURE 2.7: Mean monthly five-minute bird counts

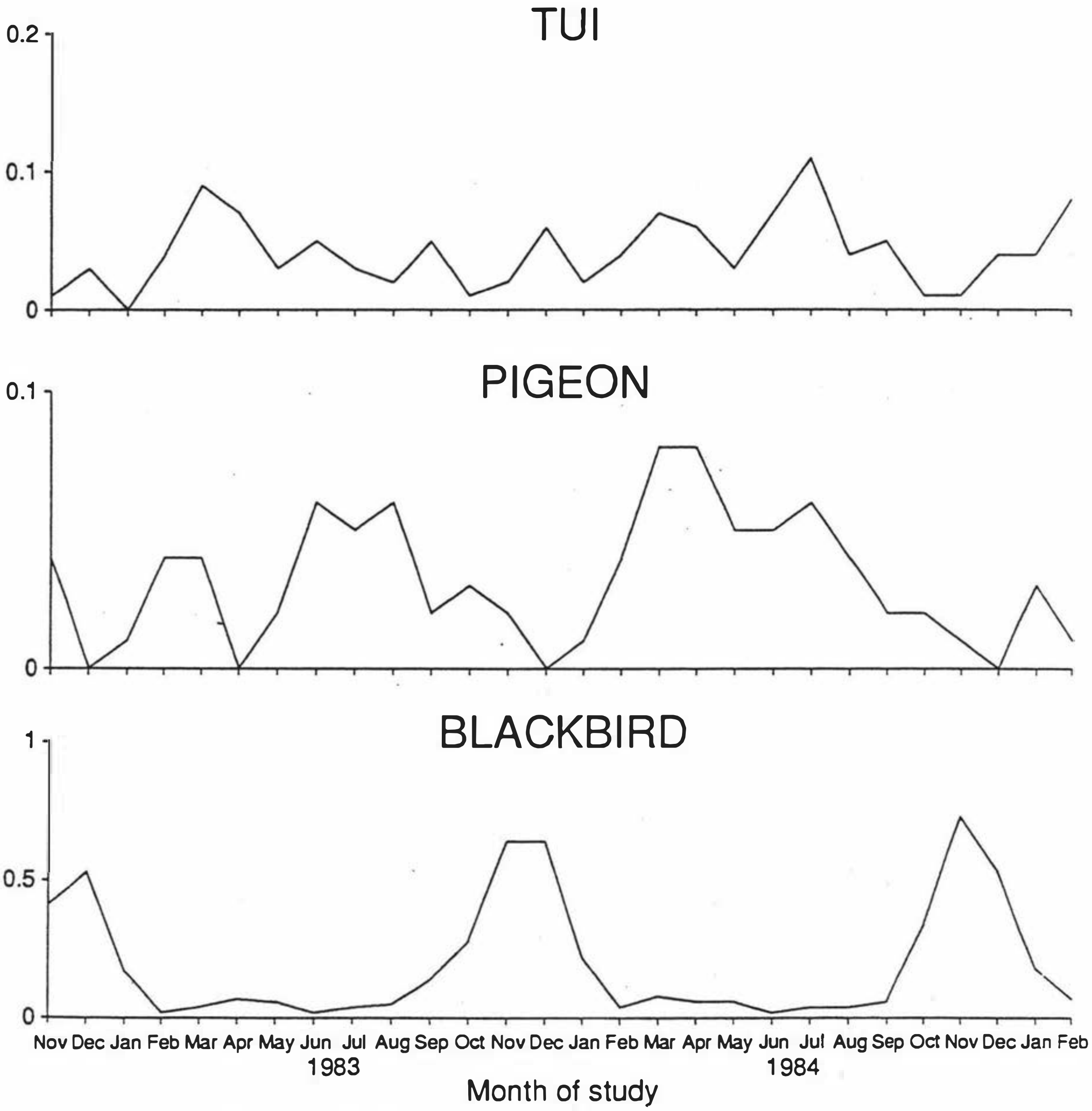

Figure 2.7: Mean monthly five-minute bird counts

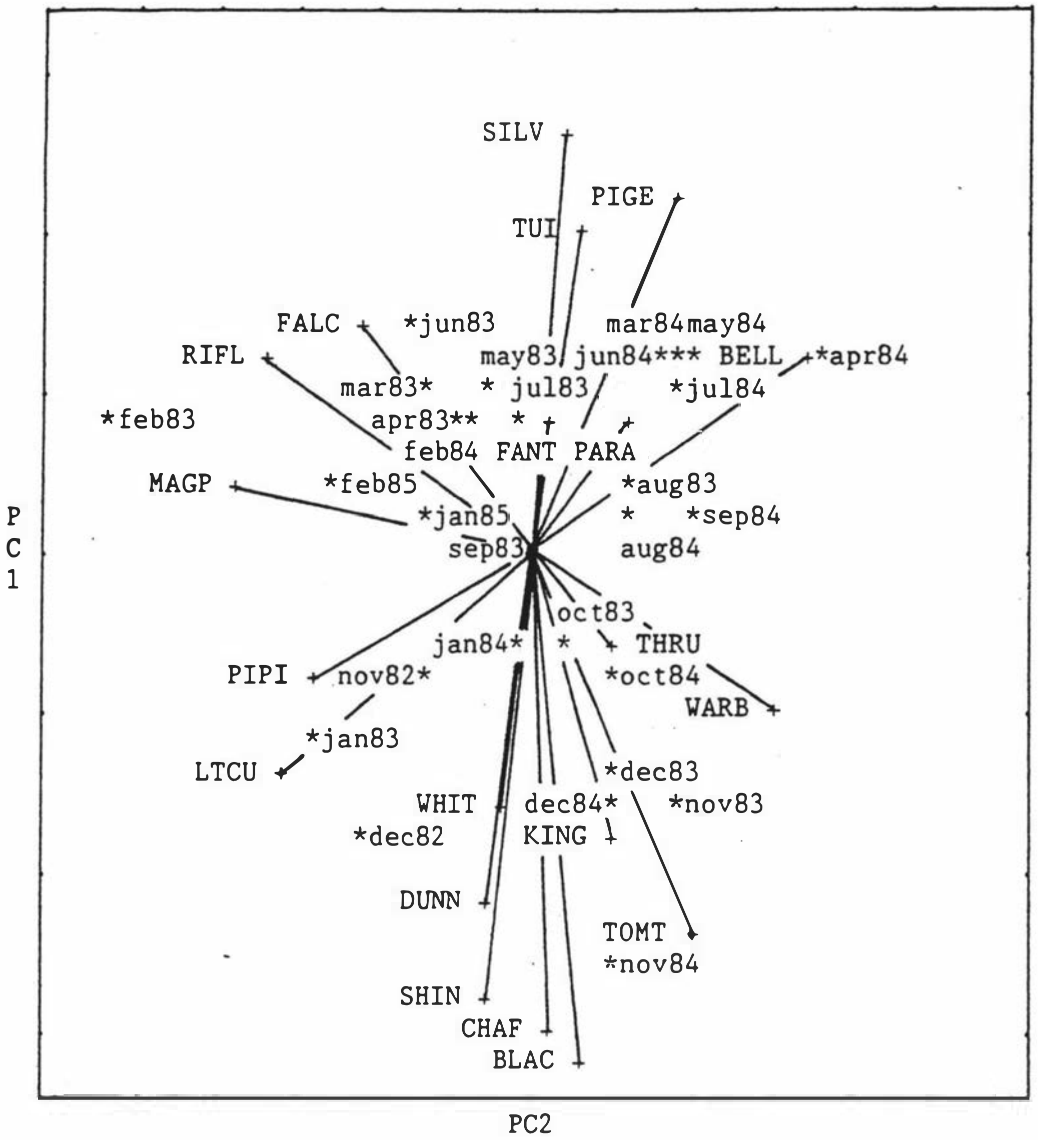

FIGURE 2.8

Principal component analysis of mean monthly five-minute bird counts

The first two principal components explained 44.1% of the variation within the data set (PC1 = 31.5%, PC2 = 12.6%). Bird species abbreviations as in table 2.2, months labeled with year. 7 of the 20 variables were skewed.

observed in much greater numbers in the first summer of the study; their vector lines are transposed toward the left and are positively correlated with the months of the first summer. Tomtits were observed in greater numbers during the subsequent summers of the study and their vector line is transposed toward the right.

The other major pattern was of those species which were observed in smallest numbers during summer; the inverse of the first pattern. A group comprised of silvereyes, tuis, pigeons and bellbirds was observed more frequently in autumn and winter than in spring and summer, with greatest numbers in 1984. Riflemen, falcons and magpies were observed in greatest numbers during February and March and lowest numbers during spring and early summer.

Warblers had a complex pattern of observed numbers with peaks in each year, during November-December and again in March. A sharp dip in numbers of warblers was observed each January. In addition, smallest numbers were observed in the first winter of the study. The numbers of fantails, falcons and thrushes observed did not vary in a predictable seasonal pattern. The short vector lines for these species indicate that the variation in numbers observed was poorly described by the first two principal components.

The cyclical nature of the birds counted in the community as a whole is demonstrated by the similar pattern of the months as described by the first two principal components (Fig. 2.8). The displacement of the months of the second year to the right was due to changes in the counts for some species over the course of the study.

The relationship of numbers observed, conspicuousness and density

To distinguish between changes in conspicuousness and changes in density the model based on the near/far ratio of birds observed was applied (Appendix 4). The data for all years were combined into monthly totals to look at the annual cycle (Fig. 2.9). Density of the rarer species could not be calculated in some months because no near birds were recorded. Also counts of these species were more susceptible to random fluctuations and so less reliable in density estimations. Comparison of the mean monthly counts with the mean density index enables better interpretation of the count data.

Chaffinches and blackbirds were observed in high numbers during the summer breeding season and low numbers at other times of the year. The density estimate for blackbirds did not change in conjunction with the numbers observed. The highest density occurred in March when the numbers observed were low. The birds were more conspicuous during the breeding season, when the males were singing. This was responsible for the large increase in counts. Density was highest at the end of the breeding season. In comparison, the density index for chaffinches changed in tandem with the numbers of birds observed. Chaffinches probably entered the study area in the breeding season but few remained there all year. The large flocks of chaffinches observed on farmland adjacent to the study area in the autumn and winter are consistent with this hypothesis.

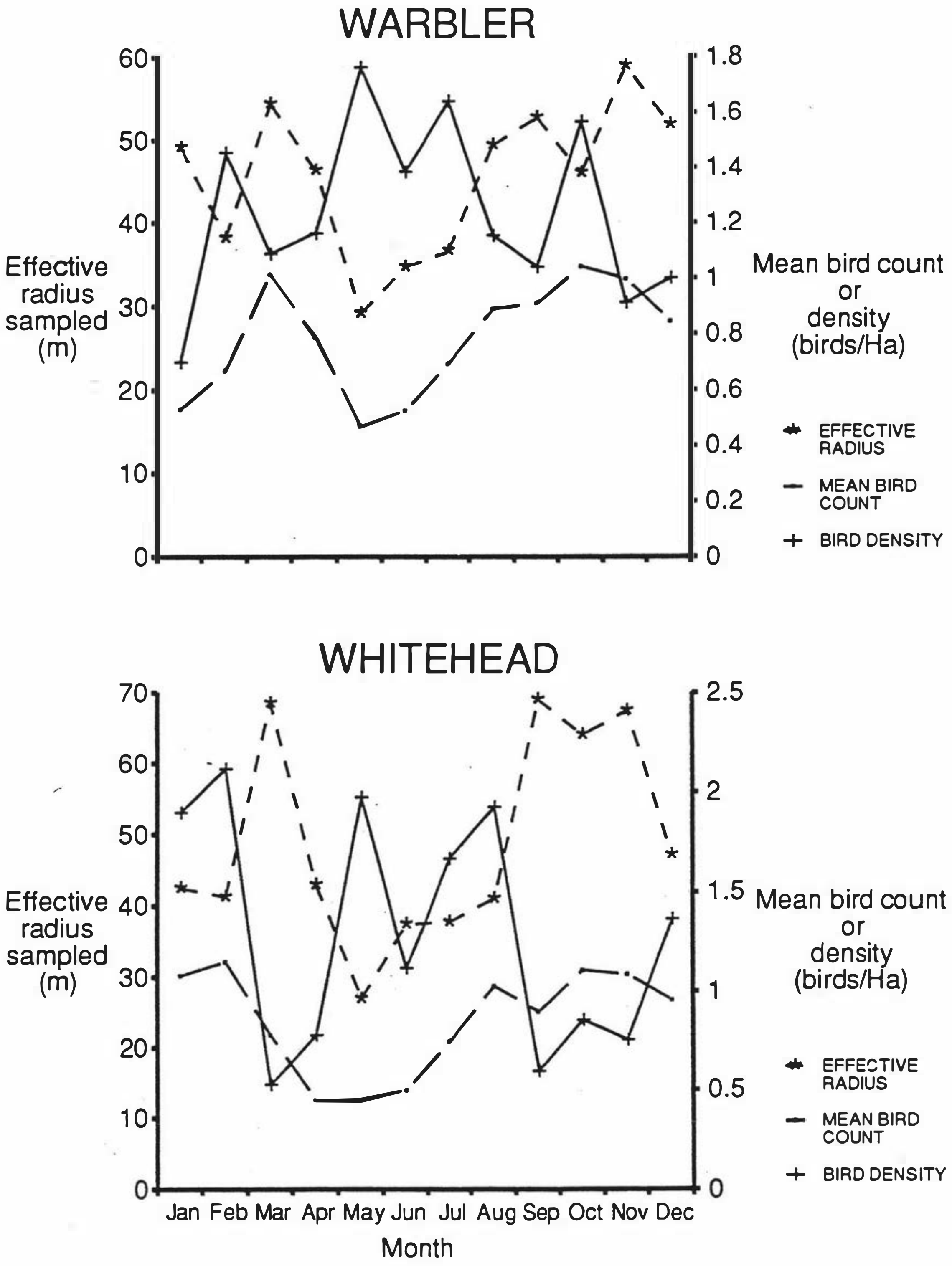

FIGURE 2.9
Annual cycles of mean five-minute bird counts, effective radii of detection and density indices

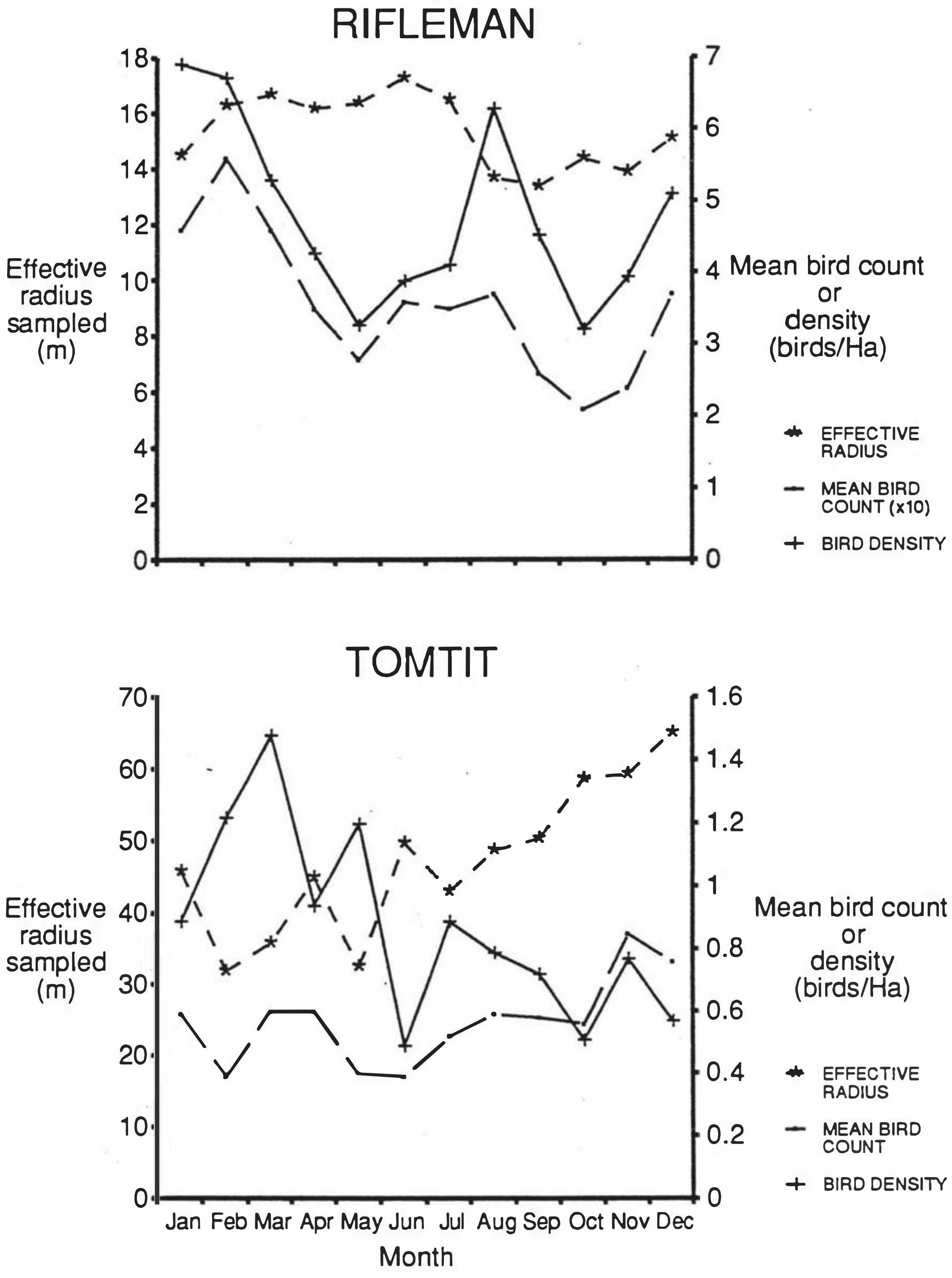

FIGURE 2.9
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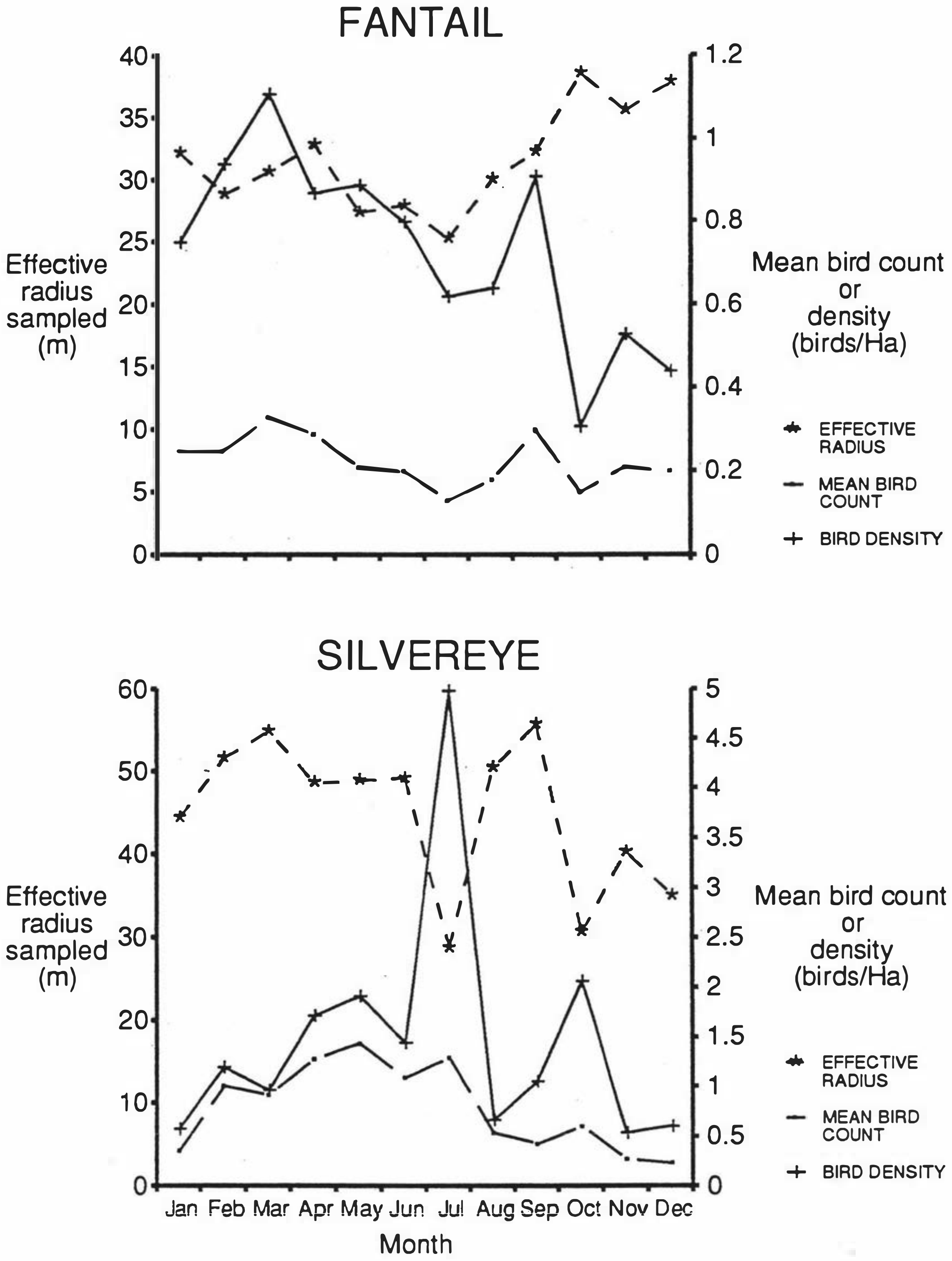


FIGURE 2.9
Annual cycles of mean five-minute bird counts effective radii of detection and density indices

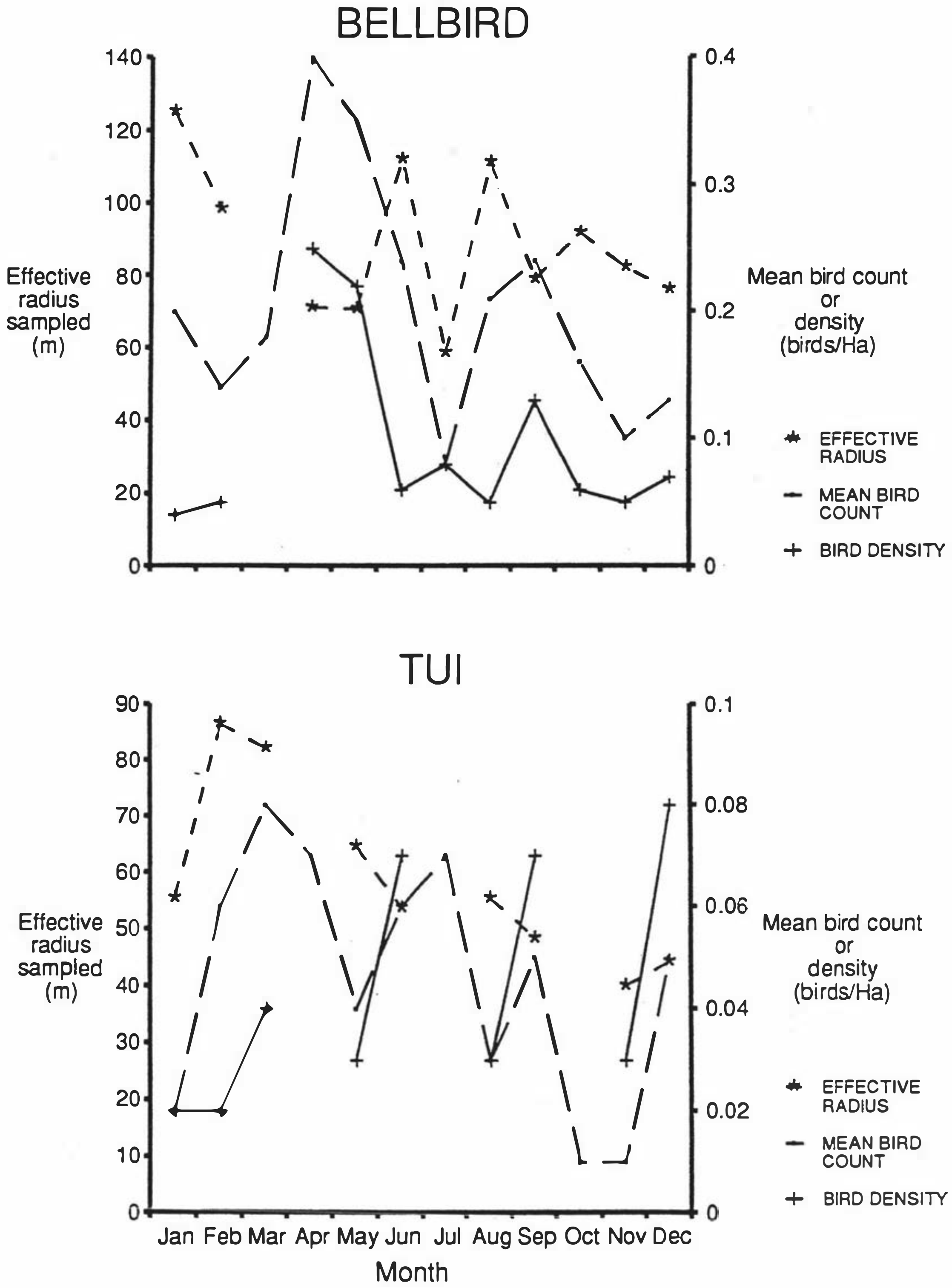


FIGURE 2.9
Annual cycles of mean five-minute bird counts, effective radii of detection and density indices

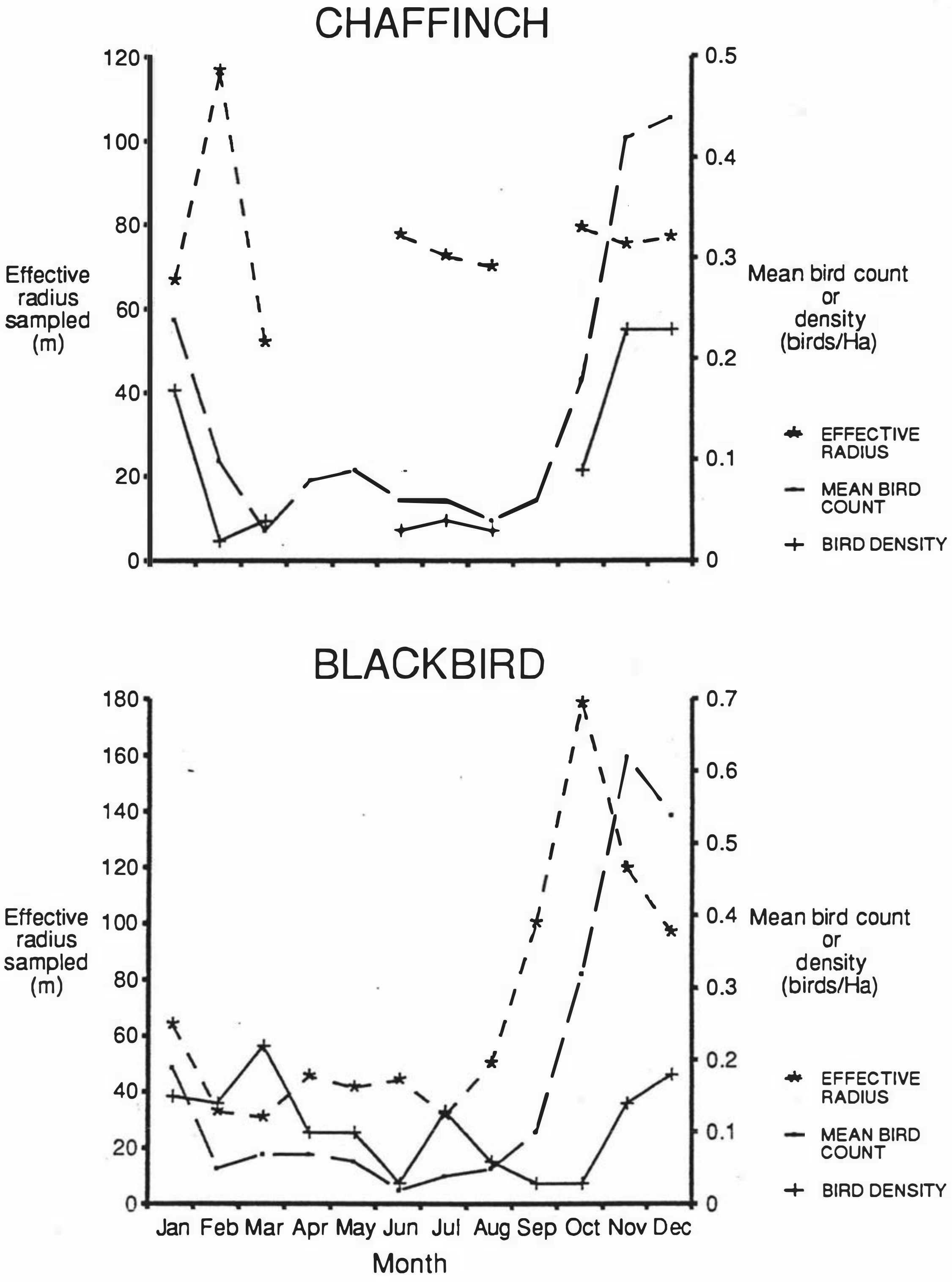


FIGURE 2.9
Annual cycles of mean five-minute bird counts, effective radii of detection and density indices

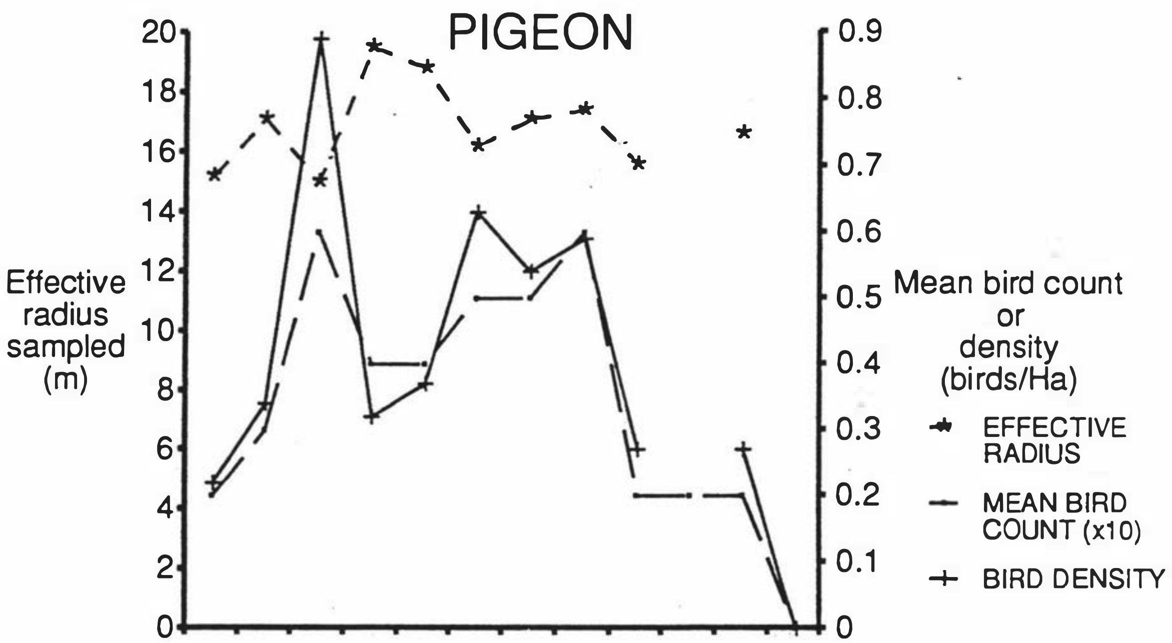


FIGURE 2.9
Annual cycles of mean five-minute bird counts, effective radii of detection and density indices

Riflemen had the smallest proportional change in density for any species. They had the lowest average effective radius of detection of any species in the study area. There was little change in conspicuousness throughout the year, and changes in numbers observed were reflected in changes in the density index. Highest densities were recorded at the end of the breeding season when large numbers of newly fledged young were seen. Riflemen were seen more often than any other species; 84% of rifleman observations were near. Consequently this species has the highest density index indicating that riflemen were the most abundant bird in the forest.

Change in numbers of warblers observed and in conspicuousness, as measured by effective radius of detection, corresponded with intensity of song as recorded by Cunningham (1955). Density did not change markedly with season. The highest density index value for this species occurred when the birds were least conspicuous in May. No full song was heard in this month and proportionally fewer far observations were recorded.

The numbers of tomtits observed peaked in November and December when the males were most conspicuous. Highest densities were recorded at the end of the breeding season in February and March when the young birds fledged. There was a decrease in density through to October and December. Fantails showed a similar pattern in density but with the peak in density slightly later in March. Fantails did not change markedly in conspicuousness with season. They sang throughout the year but were least conspicuous in winter and most conspicuous in early summer.

Whiteheads were observed in smallest numbers in April, May and June, when they were observed in flocks. During the breeding season the males defended territories and sang full song. The species was most conspicuous in early summer, but low density was calculated. Highest density occurred in late summer when the young birds fledged. High densities were also recorded in the non-breeding season when flocks of birds were seen. The non-breeding flocks were highly mobile and the same birds were probably seen several times, so the density estimate for this species would be biased upward in the winter.

Silvereyes were also seen in mobile flocks during the non-breeding season. These flocks were the largest seen within the study area, with up to 40 birds. Largest numbers of silvereyes were seen in the non-breeding season when the birds were flocking. They were generally less conspicuous in the early summer when birds left the flock to establish breeding territories. The density estimate does not fluctuate as markedly as the numbers observed with the exception of July. The large change in density estimate in that month was the result of a high number of close encounters with large flocks on transect one. As a result, large numbers of birds were seen within twenty metres of the observer and the proportion of near to far observations changed markedly. It is probable that there was some increase in numbers of silvereyes in the study area during the non-breeding season, but not as large a change as was indicated by the change in numbers observed.

Determination of changes in density and conspicuousness of the other species was hampered because of their rarity. Pigeons were very inconspicuous. Their density estimate changed in conjunction with numbers observed but, because of their scarcity, few conclusions can be drawn from this. They were observed in largest numbers when miro berries ripened in March. None were observed in December. Bellbirds and tuis were present in low numbers throughout the year but they were most conspicuous in January and February. Other species were so scarce that monthly density estimates were impracticable.

Changes in overall distribution between years

To investigate the similarities in distribution of birds observed from one year to the next the total birds counted at each group of stations in 1983 and 1984 were compared (Table 2.4). Most of the common species were observed in different distributions from one year to the next. The largest difference in distribution was observed in whiteheads which were observed in much greater numbers at the stations of transect one in 1984 with proportionate decreases in numbers observed on transect two, transect four and the associated stations. Conversely, warblers were observed proportionally less often on transect one and more often on the ridge.

TABLE 2.4

Numbers of birds observed at each group of stations in 1983 and 1984

Number of birds counted 1983

Station Group	WARB	WHIT	FANT	SILV	CHAF	RIFL	TOMT	BELL	TUI	PIGE	BLAC
1	299	111	232	367	70	100	200	41	6	0	47
2	337	583	69	300	36	179	266	78	18	41	42
3	254	505	10	250	65	170	313	64	18	5	87
4	198	150	13	84	43	166	108	55	9	2	51
5	65	18	0	125	30	2	56	26	12	1	84

Number of birds counted 1984

Station Group	WARB	WHIT	FANT	SILV	CHAF	RIFL	TOMT	BELL	TUI	PIGE	BLAC
1	316	253	275	513	53	95	193	58	5	3	33
2	421	634	82	372	95	210	237	136	43	51	78
3	411	496	20	230	54	109	318	105	9	8	99
4	275	179	26	154	46	121	189	93	8	1	54
5	102	29	0	144	32	0	59	58	9	0	54

Chi squared test of numbers observed in 1983 versus 1984

16.3	46.1	3.9	22.6	27.8	19.3	22.6	2.2	13.0	4.4	20.6
**	***		***	***	***	***				***

Significant values of Chi squared with four degrees of freedom:

p < .05	9.5	*
p < .01	13.2	**
p < .001		***

Group 1 = Stations 1-8, 17,18 = Transect one and related stations
Group 2 = Stations 9-16, 19,20 = Transect two and related stations
Group 3 = Stations 21-32, 41-42 = Forest stations of the ridge
Group 4 = Stations 33-40 = Transect five
Group 5 = Stations 43-48 = Subalpine and scrub stations

The distributions of fantails, pigeons and bellbirds were not significantly different between years. Riflemen, tuis, blackbirds and chaffinches were observed more often on transect two in 1984, silvereyes and tomtits were observed more frequently on transect five.

Seasonal movement

Movement of species within the study area was studied by comparing the proportions of each species observed on the four contour transects (one, two, four and five) each month of the study (Appendix 16). The proportion of whiteheads observed on transect four increased from July to December in each year. This coincided with the period when this species formed breeding territories, and indicated that a greater proportion of the population was at higher altitudes during this period. Other species did not move in a consistent seasonal pattern. None of the proportional changes were significantly correlated with rainfall or temperature.

2.4 Discussion

The five-minute bird count technique was originally designed to detect major differences in bird abundance between areas (Dawson and Bull 1975). Additionally, a large number of counts can be undertaken in a short period to detect these differences. Dawson and Bull noted that the topography and density of the vegetation influenced detection distances. This study has demonstrated that the use of five-minute bird counts as indices of abundance for birds of the same species in habitats of different types can be invalid. Whilst inconspicuous species varied little in their mean radius of detection between habitats, conspicuous species varied markedly with changes in habitat. For example, blackbirds were observed three times more often in the subalpine scrub than in the Mangatainoka River valley, but density estimates indicated that they were actually twice as abundant in the valley as compared to the scrub. Therefore comparisons between different areas, using standard five-minute bird counts on the same species, can be misleading.

Attempts to measure the sound characteristics of forest habitats appear doomed because of the large number of variables (Harrison and Saunders 1981, Wiley and Richards 1982). The modification of the five-minute bird count to include a distance delimiter overcame this problem. The near/far ratio can be used as a measure of conspicuousness for each species counted. The technique is not without its limitations. Large numbers of counts are required to obtain adequate near/far ratios for calculation of the density indices.

"Rare" species, which may be residents and/or breeding within the study area, present a problem for any community analysis. Techniques which derive indices of bird abundance directly, such as the Emlen technique (Emlen 1971), territorial mapping, and variable circular plot censuses, will produce density indices for these species. However, in a long term study some rarer species will inevitably be missed during some months, so researchers tend to exclude these species from their analyses.

In this study, the 11 "common" species accounted for 98% of the birds observed at the forest stations, 18 other bird species were observed, of which ten probably bred within the study area. The density indices probably represent an underestimation of total numbers of birds present. Gill (1980) equated mean annual five-minute bird counts for warblers of 0.71 and 1.03 to resident adults per hectare of 2.44 and 4.26 respectively. The mean annual five-minute bird count for warblers in this study was 0.78 but the derived density index was only 1.2 birds per hectare. The total density index for all of the common species combined was 10.9 birds per hectare.

Some of the rarely observed bird species may be important determinants of the "common" bird species distributions. Shining cuckoos parasitize grey warblers and long-tailed cuckoos parasitize whiteheads. These cuckoos migrated into the study area in the breeding season and fledglings of both species were sighted. They were most commonly observed where the densities of their host species were highest. The effect of these parasites on their host species distributions could not be investigated in this study due to the low numbers of cuckoos present.

Analysis of the bird community on the basis of diversity indices indicated that FHD was more important in determining BSD than PSD. This observation was of little value in the assessment of habitat types which were important for particular bird species. Furthermore, when I performed multivariate analyses it became apparent that plant species distributions were better predictors of bird species distribution than elements of the forest structure. Ralph (1985) studied the diversity and abundance of birds in northern Patagonia, Argentina, and observed that BSD was inversely correlated with FHD in Nothofagus forest and scrub, but plant species distributions were strongly correlated with bird species assemblages. McLay (1974) collated data from several studies of birds in New Zealand and concluded that BSD did not vary significantly between different habitat types. However, the composition of the bird community changed markedly with fewer native species and more introduced species in severely modified habitats. These observations support the conclusions of Willson (1974) that more detailed analyses are necessary for study of precise relationships in bird communities.

On the basis of PCA two groups of birds were distinguished in the study area. The first group comprised warblers, fantails, silvereyes, blackbirds and chaffinches. These species were primarily associated with tall, red beech-dominated canopy forest. The second group comprised whiteheads, pigeons, tomtits, riflemen and tuis, which were primarily associated with tall forest in which rimu and miro were evident. Finally, the distribution of bellbirds was related to the low-canopy forest of the ridge.

I have used PCA extensively to portray the inter-relationships between birds and their habitat. The raw data were normalized but scores of some species were still skewed, in addition some species responded in a nonlinear fashion. Thus, two of the basic assumptions of multivariate analysis have not been met. The interpretation of the graphs should be made with caution because of these statistical violations and the biological interpretations of the principal component axes are subject to the criticisms leveled by statisticians of biologists use of this type of test (Johnson 1981, Karr and Martin 1981). Despite these criticisms, PCA provided a clear picture of the bird community and its relationship to the environment. The first two principal components were recognized as describing specific parts of the environment in each of the analyses. The presentation of both the variables and the variates in the same graph described the most important interactions in complex multivariate situations. A large part of the variation in the original data sets was explained and where species or stations were poorly explained it is apparent in these figures. The simplification of diversity indices was avoided and meaningful relationships between specific birds and parts of the environment were elucidated.

I preferred PCA over TWINSPAN because it was more objective. The TWINSPAN analyses of the vegetation provide forest type maps which are appealing to forest managers. But these analyses required a large number of subjective decisions on the part of the researcher. The pseudospecies cut levels must be determined, and the division into a few abundance categories represents an immediate loss of potentially relevant differentiation. It is usual to perform the analysis on proportional data which ignores the absolute density of the plant species being studied, a factor which may be important as a determinant of the bird community. The level at which groups are recognized in the final output is also subjective. This criticism is applicable to all types of divisive classification.

Researchers who use unmodified five-minute bird counts cannot distinguish between changes in conspicuousness and seasonal movement

(Dawson et al. 1978, Onley 1980, Gill 1980, Harrison and Saunders 1981, Wilson et al. 1988). The modified technique used in this study was able to overcome this problem for some of the common species. For example, the number of blackbirds in the study area did not change markedly with season, although there was a great difference in conspicuousness with season. In contrast, the density of chaffinches decreased in tandem with the changes in conspicuousness, indicating movement out of the study area in the non-breeding season. The major problem with the modified technique was that large numbers of counts were needed to obtain density estimates. Only seven species could be followed for the whole annual cycle. The density index was also affected by stochastic effects in common species which flock in the non-breeding season, particularly silvereyes and whiteheads in this study.

Despite these problems two conclusions can be drawn from the comparisons of mean monthly five-minute bird counts with the density indices and effective radii of detection derived from them. Firstly, the five-minute bird counts of inconspicuous species, with effective radii of detection of less than 20 metres throughout the year, were good indicators of actual abundance. Additionally, these species varied little in detectability between habitats. The mean five-minute bird counts of pigeons and riflemen can be compared between areas and seasons although differences between observers may be important when different studies are compared (Dawson et al. 1978, Cyr 1981, Scott et al. 1981, Ramsey and Scott 1981). Secondly, the density estimates indicated that many of the resident birds were most abundant at the end of the breeding season when the young birds fledged and decreased slowly to a low point in the October-December period when females were incubating. This result is intuitively obvious, but not discernible from unmodified five-minute bird counts because of differential conspicuousness within species between seasons.

Many of the common species were counted in different proportions within the study area in 1983 and 1984, but there was no consistent pattern of change for any group of species. Comparisons of the proportions of birds counted on each of the four contour transects each month displayed surprisingly few seasonal changes in distribution. The expected proportionate increase at higher altitudes in summer was only found in whiteheads. Other studies in New Zealand have indicated that warblers, riflemen, parakeets, blackbirds, and tuis move to higher altitudes in summer (Dawson et al. 1978, Wilson et al. 1988). The absence of observed seasonal movements within my study area may be related to the relatively small area covered.

The general lack of apparent seasonal movement enhances the validity of the multivariate analysis based on species density. If seasonal movements had been observed in many of the common species several principal component analyses would have been needed to detect changes in bird habitat/relationships. The resulting increase in stochastic fluctuations of the bird density indices caused by lower numbers of counts would have made these analyses suspect. Dawson (1981b) has demonstrated that a large number of standard five-minute counts are needed to detect significant differences between habitats for rare species. In addition, he noted the possibility, borne out in this study, that detectability could vary between habitats and an estimate of density would be needed as a correction factor. He considered transect or point counts, with a near/far ratio, were the most useful compromise when measuring the abundance of forest birds (Dawson 1981c). The determination of the distribution and abundance of rare species would require a more selective sampling procedure.

None of the reported community studies of New Zealand birds have used multivariate statistical methods in their analyses, so the technique was compared with work performed overseas. Many of these studies have emphasised the relationship of bird species distributions to structural features of their habitats (James 1971, Anderson and Shugart 1974, Collins et al. 1982, James and Wamer 1982, Mehlop and Lynch 1986). In all of these studies the most significant structural determinants of bird species distributions were associated with canopy size. Variables which measured tree species compositions were confined to a few summary measures, such as percent conifers and tree species richness. Where tree species variables were included in analyses they were important in distinguishing bird species groupings.

Research in Australia verified the association of canopy height and plant species structure with bird species abundance and distribution (Recher 1969, Ford and Bell 1981, Gilmore 1985, Loyn 1985, Shields et al. 1985). However, association of bird community structures with plant species assemblages have also been observed (Loyn 1985, Milledge and Recher 1985, Gilmore 1985, Shields et al. 1985). Gilmore (1985) suggested that the structure of the vegetation was the primary determinant of bird community structure and composition. The present study has shown that bird community structure may be determined as much by tree species assemblages as by forest structure. The distributions of most of the common bird species were positively correlated with high-canopy forest; but their distributions were better explained by plant species groupings. This observation is supported by work in North America (Holmes and Robinson 1981), Argentina (Ralph 1985), Australia (Milledge and Recher 1985) and Finland (Virkkala 1988).

The resident bird community of the study area included five introduced species. The most abundant introduced birds were silvereyes. Silvereyes were self introduced from Australia and were recorded in New Zealand as early as 1832, large numbers began arriving in 1856 and breeding was observed in 1862 (Bull 1985a). Silvereyes were abundant throughout the study area particularly during the non-breeding season. They were the most common species in subalpine scrub and on transect one from February to July. The other four introduced species were imported and released by Europeans in the mid seventeenth century. Dunnocks were observed almost exclusively in subalpine scrub and tussock at an estimated density of one pair per seven hectares. Blackbirds, thrushes and chaffinches were observed in low numbers throughout the study area. The greatest densities of all three species occurred in the low altitude, red beech dominated forest. It is significant that all of the introduced species were most abundant on the margins of the forest. The density indices within the forested part of the study area for silvereyes, blackbirds and chaffinches were 1.35, 0.1 and 0.09 respectively. Thus the introduced component of the forest bird community within the study area was 14.1% of the 11 common bird species, and silvereyes alone comprised 12.4%.

The extent of the invasion of the forest habitat by introduced species is surprisingly small considering the number of bird species which have become extinct or have been lost from the Tararua Ranges. Robins (Petroica australis), huias (Hetaralocha acutirostris), kokakos (Callaeas cinerea), wekas (Gallirallus australis), saddlebacks (Philesturnus carunculatus), red-crowned parakeets (Cyanoramphus novaezelandiae), yellow-crowned parakeets (Cyanoramphus auriceps) and kakas (Nestor meridionalis) were all abundant in this area until late last century (Buller 1888, Wilkinson 1924). New Zealand thrushes (Turnagra capensis) and stitchbirds (Notiomystis cincta) were common until the middle of the nineteenth century (Buller 1888). Only yellow-crowned parakeets and kakas remain in the area, in much reduced numbers. The reduction in numbers, extinction in some cases, of so many birds in the last century is due to a variety of factors associated with the arrival of Europeans (Holdaway 1989). Predation by introduced mammals, especially feral cats and rats (Williams 1962), habitat destruction and competition with mammalian herbivores were the main causes of native bird extinctions (Holdaway 1989). Competition by introduced birds does not appear to have been important.

CHAPTER 3

FORAGING NICHES

3.1 Introduction

Lack (1954,1966) has stressed the importance of food as a limiting factor for bird populations. Most studies have been undertaken during the breeding season, when food may not be a limiting factor. In forest birds the identification of food items is difficult, and many studies of bird foraging have concentrated on the substrates from which prey are taken, the foraging technique and the foraging height (MacArthur 1958, Pearson 1971, Ulfstrand 1976, Holmes et al. 1979, Landres and MacMahon 1980, Moreno 1981, Frith 1984, Robinson and Holmes 1982, 1984, Airola and Barrett 1985, Recher et al. 1985, Holmes and Recher 1986b, Virkkala 1988). It is assumed that the mode of foraging determines which food items will be encountered (Schoener 1971, Cody 1974a). The relative importance of different plant species has also been emphasized (Hartley 1953, Balda 1969, Ulfstrand 1976, Holmes and Robinson 1981). In the present study the foraging relationships of common bird species were assessed by examining their foraging heights, tree species uses and substrate exploitation.

Seasonal changes in the foraging niches of forest bird species have been demonstrated by many authors (Gibb 1954, 1960, Stallcup 1968, Jackson 1970, Ulfstrand 1976,1977, Hogstad 1977, 1978, Alatalo and

Alatalo 1980, Morrison et al. 1985, 1986, Carrascal et al. 1987). These studies were all conducted in northern temperate woods. It has been argued that birds become less specialized in their foraging habits when food supplies are short (MacArthur and Pianka 1966, Schoener 1971, Nilsson and Alerstam 1976). Conversely Schoener (1982) argued that niche contraction should occur in periods of food shortage as a result of competition. The number of different bird species decreases in northern temperate forests during winter, possibly permitting niche expansion. In practice this does not appear to happen often. Gibb (1954), Stallcup (1968) and Alatalo and Alatalo (1980) found greater niche separation between species in winter and consequently the niche overlaps were smaller. Ulfstrand (1976) found that two species had larger niches in winter than in summer, one species had a larger niche in summer than in winter, three species showed little change in niche with season. Bell (1985) observed decreased niche breadth and overlap in autumn and winter, when food was scarcer, between thornbills (Acanthiza spp.) in a New South Wales forest. The decrease in niche breadth and overlap occurred despite an increase in the diversity of stomach contents.

The general narrowing of niche breadth by many species in winter may be associated with mixed species flocking at this time of year (Morse 1970, 1978 Austin and Smith 1972, Hogstad 1978, Alatalo 1981b, Bell 1985). In my study area seasonal changes in the composition of the avifauna, the character of the forest and the availability of invertebrate prey species are small compared to those in northern temperate forests. However, mixed species flocking does occur in winter.

In New Zealand bird community studies have been neglected. There are several rare and endangered species which have attracted a large research effort. Three authors have reported observations on the feeding niches of bird communities (Gibb 1961, Gravatt 1971, Gill 1980). Gibb compared the feeding niches of four species, Gill three species and Gravatt 12 species. None of these authors were primarily interested in community interactions, although Gravatt was specifically studying the interactions of the honeyeater guild. They did not attempt to calculate the niche breadth of any species, but Gill did calculate the overlap in feeding stations of warblers, brown creepers and silvereyes. In my study the foraging relationships of the common bird species were examined in detail. Sequential observations were taken and the sample sizes for both the number of individuals observed and the total number of observations were reported. Further analyses of foraging niches were undertaken only for those species which were observed on more than 30 separate occasions (Morrison 1984).

New Zealand has an impoverished land bird fauna as a consequence of geographical isolation and severe habitat modification caused by human influence. Comparison of bird community structure with similar studies in other countries, particularly Australia, is interesting in terms of several ecological theories. Biogeographical theory (MacArthur and Wilson 1967, Diamond 1970) in conjunction with optimization theory (Schoener 1971, Pyke et al. 1977) predicts that species will have larger niches than congeners on the mainland. The status of introduced species and their integration with the native avifauna is interesting. Many native species have become extinct or rare within the past 200 years as a result of habitat modification and predation by introduced mammals. The resources these species used have become accessible to both the remaining native species and the introduced species. The foraging niches of the birds of the study area are discussed in the light of this historical perspective.

3.2 Methods

From January 1983 until February 1985 the following data were recorded every time a bird was seen:

1. The date.
2. The nearest bird counting station.
3. The New Zealand Standard Time at the start of the observation.
4. The wind noise on a subjective scale:
    0 = calm
    1 = some leaf movement no noise heard
    2 = distant rustle
    3 = immediate noise, twigs and small branches moving
    4 = immediate noise with gusts, branches moving
    5 = continuous high wind
    6 = gale, leaves being stripped off trees
5. The cloud cover measured in octas.
6. The canopy height, estimated by eye to the nearest metre.
7. The total duration of the observation in seconds.
8. The bird species.
9. The tree species which the bird was using.
10. The height of the bird, estimated by eye to the nearest metre and

then amalgamated into two metre intervals.

11. The part of the habitat being used by the bird species:

(Atkinson 1966)

0 = ground

1 = twig

2 = small branch

3 = large branch

4 = limb

5 = trunk

6 = foliage

7 = flower

8 = fruit

9 = air

12. Whether the part of the tree which the bird was using was alive or dead.

13. Bird behaviour.

0 = feed including active searching

1 = perch

2 = sing or call

3 = preen

4 = court

5 = fly

6 = aggression both intra-specific and inter-specific

These data were recorded in the field using a hand-held tape recorder. The data were transcribed in the laboratory and the bird behaviour and position updated at 15 second intervals. The method is equivalent to the metronome technique of Wiens et al. (1970). No attempt was made to follow birds through the forest, so all observations were on specific transects. A maximum time of ten minutes of sequential observations on a single individual was set to reduce bias. Each set of observations for a single bird was called a period.

From March 1984 until February 1985 birds were also observed from a canopy observation site, set at 13 metres above the ground in a rimu tree near to station 19. Observations were spread so that the period from one hour after sunrise until one hour before sunset was covered for a full day in each month at the canopy station.

A G-test (Sokal and Rohlf 1981) was used to compare the effect of non-independence of sequential observations. The sum of all first ground station observations in each period for each species was compared with the sum of all subsequent observations. The grouping criteria were arranged so that few of the expected values were less than five.

Seasonal changes of foraging niche were analysed for ground observations by pooling the data for different years. To investigate changes in niche over the course of the year four seasons were defined:

Summer = December, January and February
Autumn = March, April and May
Winter = June, July and August
Spring = September, October and November

For comparisons between seasons the number of observations were standardized by taking all of the observations in the season when a bird species was least observed and a random sample of the same number for each of the other seasons.

The proportions of different tree species present where bird species were actively foraging were calculated by using point height intercept (PHI) data collected in the associated botanical study. The PHI data were used as measures of the available tree surface at each station. These proportions were multiplied by the number of observations of each bird species at each station to give an expected number of foraging observations. A Wilcoxon signed-rank test was performed on the expected/observed pairs to indicate species preferences in foraging substrates. Because riflemen were observed foraging mainly on larger woody surfaces an alternative measure based on the diameter at breast height (DBH) of the tree species at each station was calculated for this species.

3.3 Results

There were large differences in the number of observations of each species (Table 3.1). Data on habitat use and behaviour are presented in appendices 9 to 16.

TABLE 3.1

Number of niche observations of each bird species

	Total P	Total I	Ground P	Ground I	Ground Mean P Secs.	Canopy P	Canopy I	Canopy Mean P Secs.
Warbler	466	2157	377	1774	77.51	89	383	71.24
Whitehead	556	2809	440	2278	84.25	116	531	76.17
Fantail	341	1407	250	1061	69.27	91	346	64.37
Silvereye	129	374	82	288	59.33	47	86	32.43
Chaffinch	33	123	17	90	87.41	16	33	34.94
Rifleman	491	2286	437	2064	76.84	54	222	69.41
Tomtit	294	1182	259	1057	67.44	35	125	59.89
Bellbird	34	150	28	128	75.25	6	22	61.83
Tui	41	294	22	143	104.27	19	151	127.05
Pigeon	54	921	42	691	249.74	12	230	292.50
Blackbird	59	74	59	74	8.90	0	0	0.00

P = period I = Interval
Mean P = Mean length of periods in seconds

A period consisted of observations on a single bird for up to 10 minutes. Within each observation period the behaviour and position of the bird was recorded every 15 seconds, these individual observations were called intervals. Observations at the canopy station were separated from observations at the ground.

Canopy station observations and ground station observations were considered separately. Chaffinches, bellbirds, tuis and pigeons were observed foraging on fewer than 30 periods in both sets of observations and were excluded from statistical analyses. A short appraisal of each of these species follows.

Pigeons were observed on 54 periods, most of which were of considerable duration (Table 3.1), they foraged mainly on miro fruit in large trees at heights of over 12 metres. They used these fruits throughout the year with the exception of December when no pigeons were observed in the study area. In December and January pigeons were observed in farmland adjacent to the study area foraging on the foliage and seeds of tree lupin and the foliage of willow. Pigeons were also observed foraging on mahoe, supplejack and horopito fruits during five-minute bird counts within the study area. They were the only species observed using these seeds and berries and consequently their feeding niche did not overlap with any other species. Active foraging occurred in bouts interspersed with long periods of perching.

Tuis were observed most often in January and February when the northern rata flowered. There were few of these trees in the study area, but they flowered prolifically. Of the active foraging by tuis 47% of the ground observations and 78% of the canopy observations were on northern rata flowers. Eight (13.6%) of the other canopy foraging observations were on climbing rata flowers in March and April. The other foraging observations were of tuis gleaning from woody surfaces, principally large branches of kamahi. The nectar-feeding observations on northern rata trees were at a height of approximately 30 metres, whereas the wood-gleaning observations were at heights of eight to eighteen metres. Tuis spent a large proportion of their time singing and perching. They actively excluded bellbirds from northern rata trees.

Bellbirds gleaned from small and intermediate sized woody surfaces and from foliage, mainly on kamahi and red beech. However, the utilisation of red beech occurred in only one observation period which lasted 414 seconds and included 22 active foraging observations. This represented nearly 40% of the ground foraging observations and was an obvious source of bias. Active foraging was observed at heights ranging from 2 to 23 metres with most of the foraging on kamahi at heights of 7 to 12 metres. Bellbirds were often observed singing and perching.

Chaffinches were observed gleaning from both wood and foliage in approximately equal proportions. They used a variety of trees, of which kamahi, miro, red beech, leatherwood and toro were the most common. Most foraging observations were of birds at heights of less than 12 metres. Chaffinches were often observed singing and perching. Males sang at the top of the canopy at heights of up to 24 metres. It was difficult to see the top of the canopy in observations from the ground, but at the canopy station 27 of the 33 observations were of singing birds.

Of the seven remaining species, warblers, whiteheads, silvereyes, riflemen and blackbirds were primarily observed foraging. Fantails and tomtits were generally observed perching. Both of these species used perch sites to survey their foraging areas and then sallied forth to capture prey. Additionally, these two species were observed singing or calling approximately 25% of the time.

The use of sequential observations on the same individual was compared with single observations on each individual (Table 3.2). Blackbirds were not included in this analysis because they foraged only on the ground. Changing the observation technique significantly changed the observed habitat utilisation of several species. The differences in height utilisation for warblers, whiteheads and riflemen occurred because a greater proportion of the first observations were at heights of two metres or less.

Before going into greater detail short descriptions of the foraging niches of the seven remaining species are:

Warblers gleaned primarily off foliage on kamahi, red beech, toro and miro.

Whiteheads gleaned primarily off smaller woody surfaces on kamahi, rimu, miro and red beech.

Fantails fed primarily in the air.

Silvereyes gleaned off foliage and small woody surfaces on red beech, kamahi, toro and broadleaf. They also used nectar from rata when it was available and occasionally small-leaved Coprosma fruit.

Riflemen gleaned primarily off larger woody surfaces on kamahi, toro and red beech.

Tomtits were difficult to observe foraging on the ground because of the extensive ground cover, so their use of that substrate (37.7%) is probably underestimated. They also foraged on woody surfaces and foliage of kamahi, toro and red beech.

Blackbirds fed exclusively on the ground.

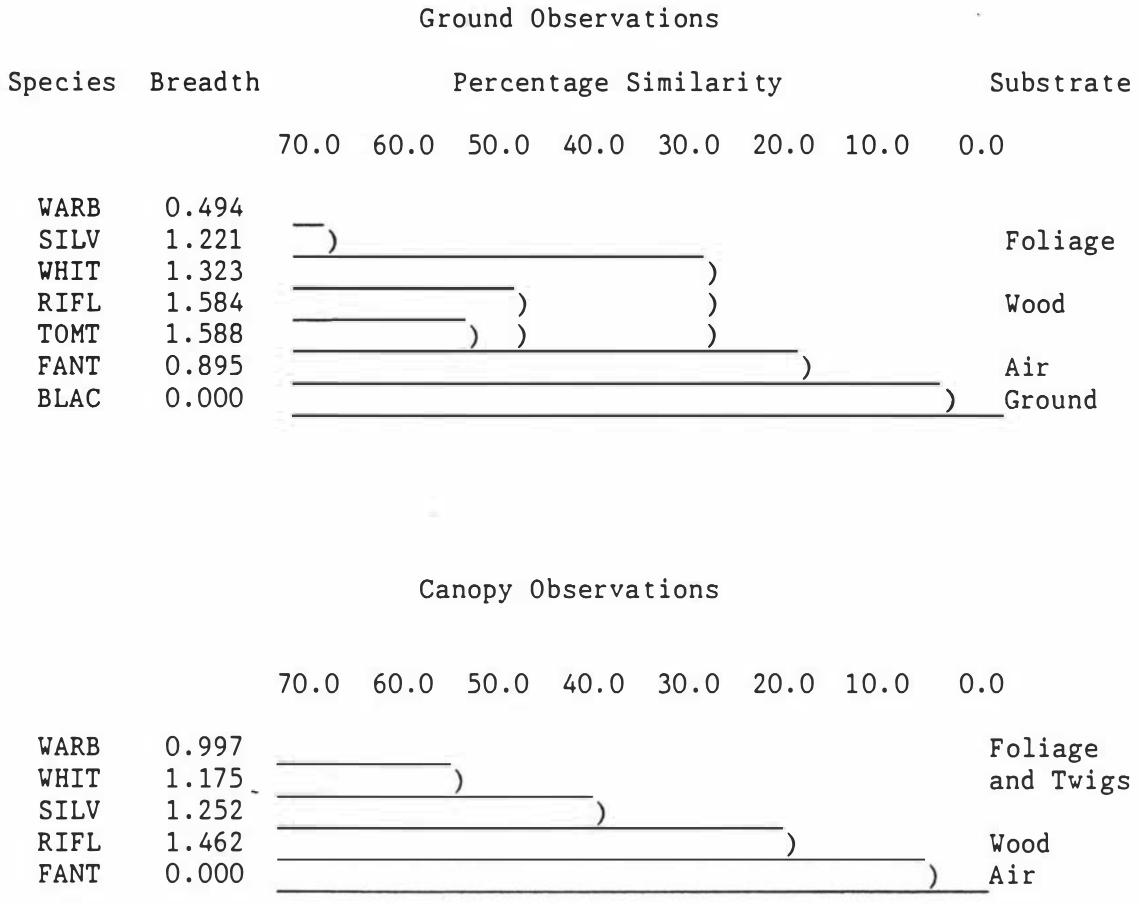
Cluster analysis of substrate use distinguished four guilds at the 50% level of similarity (Fig. 3.1). Ground foraging could not be seen from the canopy station and consequently there were no observations of blackbirds and only four observations of tomtits. The four guilds recognized from the ground were foliage-gleaning (warblers and silvereyes), wood-gleaning (whiteheads, riflemen and tomtits), air-sallying (fantails), and ground-foraging (blackbirds). There were some changes in guild structure and membership at the canopy station. Fantails and riflemen remained in their guilds. However, silvereyes were categorized in a nectar-feeding guild. Whiteheads and warblers were grouped in a foliage/small woody surface-gleaning guild. These differences can be explained by the outlook from the canopy station. Firstly, two large northern rata trees could be seen from the canopy station and these trees were rare in the study area but flowered prolifically. Hence the large proportion of nectar-feeding observations by silvereyes. Secondly, the majority of trees seen from the canopy station were rimu, and the twigs and foliage of these trees were difficult to distinguish from one another. Hence warblers, which glean extensively off foliage, and whiteheads, which glean mainly off twigs, overlapped. Members of the wood-gleaning guild showed the widest niche breadth, probably because half of the substrate categories

TABLE 3.2

G values calculated from a comparison of first foraging observation with subsequent foraging observations

Bird Species	Substrate		Tree Species		Height Interval	
	G	DF	G	DF	G	DF
Warbler	11.140*	3	26.605**	11	41.523**	14
Whitehead	.999	5	6.200	7	34.843**	17
Fantail	.830	1	5.666	2	1.732	5
Silvereye	15.029**	2	3.858	3	13.208	9
Rifleman	11.368*	5	8.556	9	44.168**	13
Tomtit	6.628	3	.143	2	1.615	4

* = $P < 0.05$ ** = $P < 0.01$



Ground Observations

Canopy Observations

FIGURE 3.1

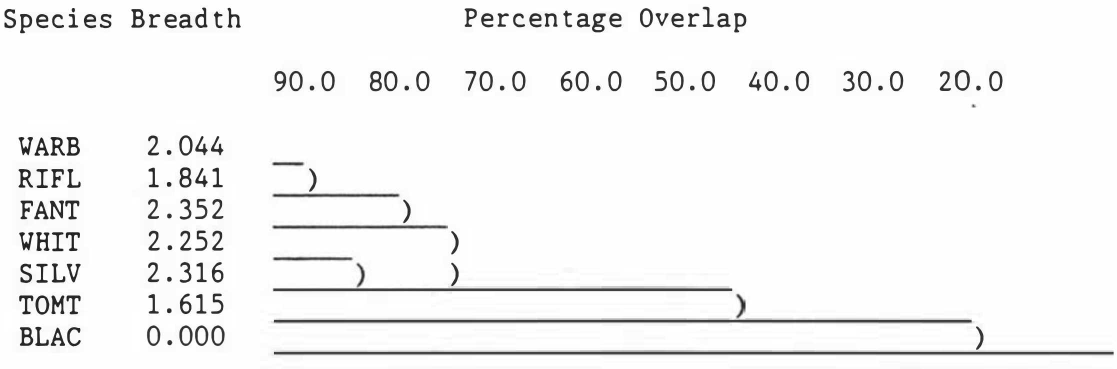
Dendrograms of foraging substrate overlaps

Bird species abbreviations as in table 2.2.

were different types of woody surface.

The foraging height utilisations were markedly higher at the canopy station than those observed from the ground (Appendix 12). This occurred because of bias due to the position of the observer and because the canopy height at station 19 was markedly higher than the average for the study area. It was difficult to observe birds in the upper layers of vegetation from the ground because of intervening foliage, and the converse was true at the canopy station. Although most species foraged over a wide range of heights some vertical stratification of the bird community was evident particularly at the canopy station. Blackbirds were the only birds observed from the ground to have a narrow foraging height breadth (Fig. 3.2). Because all of the feeding observations of this species were on the ground all were at zero height, giving a foraging height niche breadth of zero. Tomtits foraged mainly on or near the ground and had the second lowest foraging height breadth. Warblers and riflemen both used a wide range of height strata but both tended to use heights of four to eight metres. These species had the highest overlap when observed from the ground. The canopy observations were higher with less overlap, warblers averaged slightly higher height utilisations than riflemen (Fig. 3.2, Appendix 12). Whiteheads, fantails and silvereyes were all observed using a wide range of strata. The canopy station observations of these three species showed less overlap and more vertical stratification. Silvereyes foraged in the large northern rata trees 55% of the time at this station, which caused an increase in their foraging height utilisation profile.

Ground Observations



Canopy Observations

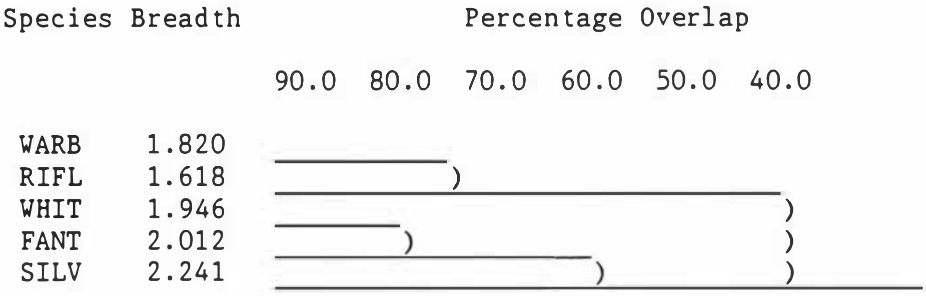
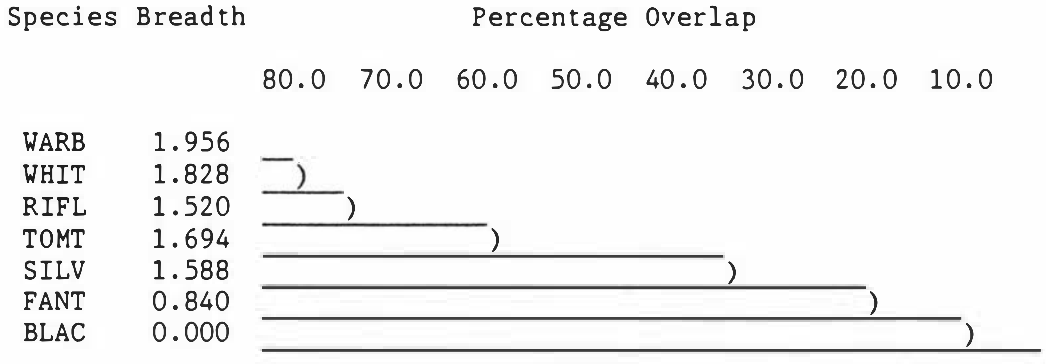


FIGURE 3.2

Dendrograms of foraging height overlaps

Birds species abbreviations as in table 2.2.

Ground Observations



Canopy Observations

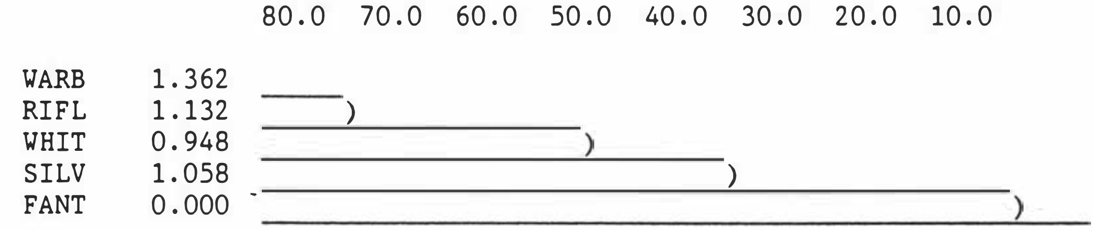


FIGURE 3.3

Dendrograms of foraging tree species overlaps

Birds species abbreviations as in table 2.2.

In ground observations warblers, whiteheads, riflemen and tomtits were grouped by their tree species use (Fig. 3.3), mainly because of their extensive use of kamahi. Warblers and whiteheads had the greatest amount of overlap in tree species utilisation (Fig. 3.3). Both used kamahi over 40% of the time, with red beech, toro and miro also being utilised, but whiteheads were more frequently observed on rimu. Riflemen had a higher proportional use of kamahi (63.5%). In addition to their use of tree species as foraging substrates tomtits used the ground (37.7%). Silvereyes were grouped by themselves because of their high use of red beech (59.3%). Fantails made little use of any tree species, foraging mostly in the air (79.7%). Blackbirds foraged exclusively on the ground.

In canopy station observations the number of tree species that could be seen was limited, the common bird species were observed foraging on seven tree species. However, the amount of overlap in tree species utilisation between bird species was similar to the overlap derived from ground observations (Fig. 3.3). Warblers and riflemen overlapped 70.8%, they were characterized by their use of rimu, miro and kamahi. As in the ground observations, riflemen used kamahi extensively (52%). The extent of overlap between whiteheads and warblers was less at the canopy station than in the ground observations because whiteheads used rimu predominantly (70.4%). Silvereyes foraged on northern rata flowers (55.1%) and on rimu (33.3%). Fantails foraged exclusively in the air at the canopy station and had little overlap with any other species.

Preferential foraging use of tree species by bird species could not be inferred directly from the ground observations because the number of observations at each station was not uniform. Blackbirds and fantails used the ground and the air respectively for foraging and thus did not have preferred tree species. The other species were analysed for preferential use by discarding foraging observations in the air, on the ground and on non-woody plant species. The 12 most abundant tree species were analysed (Table 3.3) for bird species preferences. Most of the common bird species preferentially used different tree species. Tomtits did not preferentially use any tree species, probably a reflection of their extensive use of the ground. Tree ferns were avoided by all species with the exception of tomtits.

The canopy station observations allow a more direct comparison between species (Appendix 11). The preferences of whiteheads for rimu and riflemen for kamahi remain the same. However, silvereyes were not observed using the red beech tree that could be seen from the canopy station but used the northern rata trees extensively. Tomtits were observed foraging on only four occasions and no inferences can be drawn from these data. Warblers used rimu, miro and kamahi in approximately equal proportions. This contradicted the avoidance of rimu evident from the ground study.

TABLE 3.3

Preferential use of tree species by foraging birds

	WARB	WHIT	SILV	RIFL	TOMT
RIMU	--	+			--
MIRO			--		-
HALL		--	--		
PHYL				--	
RBEE			+	-	
KAMA			--	+++	
MAHO				++	-
TORO	++				-
BRDL					--
AXIL		--			
COLO		--			
TFER	-	---	---	---	

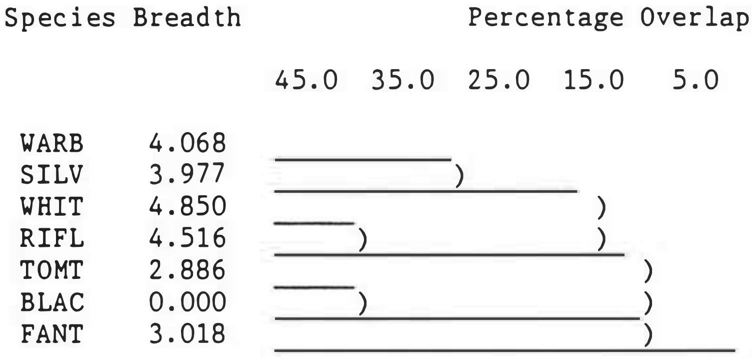
Wilcoxon signed ranks test + = $p < .05$ preference
++ = $p < .01$ preference
+++ = $p < .001$ preference
- = $p < .05$ avoidance
-- = $p < .01$ avoidance
--- = $p < .001$ avoidance

The foraging niches and foraging overlaps were further defined by analysis of substrate, height and tree species utilisation concurrently. This decreased the extent of overlap considerably (Fig. 3.4). Tomtits were now grouped with blackbirds because both used the ground as a foraging substrate, which was classified into the same height and tree species classes. Their total overlap was 37.7% which was the proportion of observations that tomtits were observed foraging on the ground. The other species remained in the groups defined by substrate usage alone. Whiteheads and riflemen overlapped 36.0%, mainly because of their joint use of woody surfaces, principally of kamahi, although rimu, miro, red beech and toro were also important. Warblers and silvereyes overlapped 28.8% because of their joint use of foliage and some of the smaller woody surfaces of red beech, kamahi and toro.

The seasonal foraging niche breadths and overlaps were calculated and compared for ground observations only (Table 3.4). Blackbirds were not included in these analyses because they foraged solely on the ground. Seasonal niche breadths for fantails, silvereyes and tomtits were unreliable because all breadths and overlaps were standardized by reduction to equal the season in which fewest observations were recorded. All species, with the exception of silvereyes, had narrowest substrate niche breadths in winter (Table 3.4). The seasonal foraging niche breadths based on height and tree species did not vary in a predictable pattern (Table 3.4). Multidimensional seasonal foraging niches, which were calculated by analysis of substrate, tree species and height utilisation simultaneously, also did not vary in a predictable pattern. The mean overlaps of bird species use of all three niche dimensions were smallest in winter and largest in summer (Table 3.5). The largest differences in mean overlaps between seasons were apparent in the use of substrate.

The seasonal foraging niches of the three most commonly observed species, warbler, whitehead and rifleman, were examined in greater detail. All three species significantly changed their utilisation in each of the three niche dimensions (Chi squared, $p < .001$). Despite these differences the predominant foraging sites in each species remained constant (Appendices 14, 15, 16). The substrate profile usage of tomtits and silvereyes varied markedly. This may have been a reflection of the low number of observations for each of these species in some seasons. Tomtits were observed primarily foraging on the ground in winter, spring and autumn, but in summer they foraged mainly on woody surfaces. Silvereyes foraged on foliage more than 50% of the time in all seasons except autumn, when they foraged more on woody surfaces.

Ground Observations



Canopy Observations

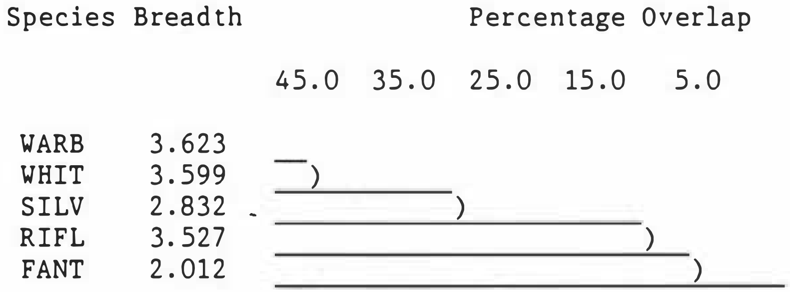


FIGURE 3.4

Dendrograms of multidimensional foraging niches

Bird species abbreviations as in table 2.2

TABLE 3.4
Seasonal foraging niche breadths and evenness

Substrate foraging niche breadth and evenness

	Summer		Autumn		Winter		Spring	
	H	J	H	J	H	J	H	J
WARB	.547	.238	.463	.201	.302	.131	.637	.277
WHIT	1.293	.561	1.368	.594	1.266	.550	1.286	.559
FANT	1.306	.567	.795	.345	.173	.075	.398	.173
SILV	1.164	.506	.996	.432	1.156	.502	1.249	.543
RIFL	1.570	.682	1.575	.684	1.506	.654	1.585	.688
TOMT	1.682	.731	1.374	.597	.483	.210	1.241	.539

Height foraging niche breadth and evenness

	Summer		Autumn		Winter		Spring	
	H	J	H	J	H	J	H	J
WARB	1.902	.686	2.008	.724	2.107	.760	2.035	.734
WHIT	2.200	.793	2.167	.782	2.260	.815	2.061	.743
FANT	2.338	.843	1.897	.684	2.257	.814	2.243	.809
SILV	2.062	.744	1.773	.640	2.135	.770	2.155	.777
RIFL	1.697	.612	1.891	.682	1.844	.665	1.858	.670
TOMT	1.790	.646	1.243	.448	.602	.217	1.067	.385

Tree species foraging niche breadth and evenness

	Summer		Autumn		Winter		Spring	
	H	J	H	J	H	J	H	J
WARB	1.798	.484	1.896	.511	1.951	.525	1.673	.451
WHIT	1.798	.484	1.931	.520	1.675	.451	1.549	.417
FANT	1.172	.316	.748	.202	.173	.047	.398	.107
SILV	1.273	.343	1.742	.469	1.166	.314	1.020	.275
RIFL	1.492	.402	1.531	.412	1.252	.337	1.578	.425
TOMT	1.827	.492	1.292	.348	.483	.130	1.414	.381

Multidimensional foraging niche breadth and evenness

	Summer		Autumn		Winter		Spring	
	H	J	H	J	H	J	H	J
WARB	3.728	.648	3.855	.670	3.662	.636	3.542	.615
WHIT	4.593	.798	4.551	.791	4.369	.759	4.042	.702
FANT	2.904	.504	2.485	.432	2.337	.406	2.453	.426
SILV	2.659	.462	2.859	.497	3.440	.598	2.831	.492
RIFL	4.314	.750	4.204	.730	3.973	.690	4.058	.705
TOMT	3.182	.553	1.938	.337	.602	.105	1.540	.268

H = Niche breadth   J = evenness
Bird species abbreviations as in table 2.2.

TABLE 3.5
Mean seasonal foraging overlaps

Mean substrate foraging niche overlaps

```
Season    N      Mean     Stdev   Individual 95% confidence intervals
                                   based on pooled standard deviation

Summer   15     0.3898    0.1716                     (-------*--------)
Autumn   15     0.2711    0.1779            (-------*-------)
Winter   15     0.1623    0.1964  (--------*-------)
Spring   15     0.2497    0.1985          (-------*-------)
                                  -----+---------+---------+---------+-
                                    0.12      0.24      0.36      0.48

Pooled standard deviation = 0.1865
```

Mean tree species foraging niche overlaps

```
Season    N     Mean     Stdev   Individual 95% confidence intervals
                                  based on pooled standard deviation

Summer   15     0.4735    0.2071                        (--------*-------)
Autumn   15     0.3537    0.1963                (-------*--------)
Winter   15     0.2545    0.2439         (-------*--------)
Spring   15     0.2837    0.2504           (-------*--------)
                                 -+---------+---------+---------+-----
                                0.14      0.28      0.42      0.56

Pooled standard deviation = 0.2256
```

Mean height foraging niche overlaps

```
Season    N      Mean     Stdev   Individual 95% confidence intervals
                                   based on pooled standard deviation

Summer   15     0.6260    0.1375                     (--------*---------)
Autumn   15     0.5613    0.1955               (---------*--------)
Winter   15     0.4733    0.2756  (--------*---------)
Spring   15     0.5067    0.2377     (--------*---------)
                                  ---------+---------+---------+------
                                         0.48      0.60      0.72

Pooled standard deviation = 0.2177
```

3.4 Discussion

Many studies of avian foraging niche have been on large diverse bird communities with many species in each guild, while in the present study only seven species were considered in detail. The theory of island biogeography predicts niche expansion in isolated biotas (MacArthur and Wilson 1967). Large niche breadths were not observed in this study and foraging niche overlaps were low in comparison to northern hemisphere work (Herrera 1978, Alatalo 1981b, 1982, Landres and MacMahon 1980, 1983, Moreno 1981, Saether 1982, Airola and Barrett 1985, Laurent 1986, Virkkala 1988).

It has been argued that non-migrant birds in northern temperate forests must be opportunistic in order to cope with large fluctuations in resource availability (Morse 1971). New Zealand rain forests are evergreen and large increases in numbers of insects in spring and summer do not occur. Food resources for insectivorous species are relatively constant throughout the year in New Zealand, with a small seasonal peak in summer (Moeed and Fitzgerald 1982). Optimal foraging theory (Pyke et al. 1977) predicts specialisation of feeding niche in this situation as a super-abundant resource does not occur at any one food site each year. This may also explain why foraging height was less important in diferentiating species foraging niches. When a super-abundant resource is available at one particular site separation in height becomes more important if competition is causing foraging niche separation (Saether 1982).

Complementarity in foraging niche axes was not observed which could lead to the conclusion that competition is of minor importance in determining foraging niche (Cody 1974a, Schoener 1974, Pianka 1978). However, this conclusion is dependent upon the unlikely event that niche axes are independent and of equal importance (Alatalo 1982). Evoking competition as the causative mechanism for patterns of resource use involves circular reasoning (Landres and MacMahon 1980, Simberloff 1983). Without experimental manipulation of the resources such arguments are conditional upon the rejection of alternate hypotheses (Alatalo et al. 1986). Therefore I can conclude that the foraging axes studied, particularly foraging site, are important in community organization, but cannot positively ascribe these differences to competition. However, studies of changes in habitat selection in periods of mixed species flocking tend to corroborate the hypothesis that competition on foraging niche axes are important determinants of community structure (Morse 1970, 1978, Austin and Smith 1972, Hogstad 1978, Alatalo 1980, 1981b, Alatalo et al. 1985, 1986, Rabol 1987).

The low multi-dimensional niche overlaps obtained by consideration of the three foraging dimensions concurrently illustrate the point made by May (1975) that true niche overlaps cannot be estimated from consideration of single dimensions sequentially. Conversely, Feinsinger (1976) has noted that in considering multidimensional niche space the number of observations per category will decrease. The results become unreliable and niche breadth and overlap will be underestimated. This was the case with my data where a 17x19x10 (height x tree species x substrate) matrix was produced in considering the multidimensional niches. Despite this criticism, the introduction of these extra dimensions reclassified tomtits into what is probably their correct guild illustrating the importance of considering multidimensional niche measures.

Comparisons of the niches of different species based on ground observations were biased because the proportions of observations of each species were different throughout the study area. The structure and composition of the vegetation of the study area varied (Chapter 1) and so some of the relationships between bird species were obscured. The degree of vertical stratification within the bird community did not become apparent until the canopy station data were examined. This type of problem will occur in any study area with structural and/or vegetational diversity but is rarely considered in the literature.

Analysis of bird species use of tree species indicated which tree species were used more/less than statistically expected. To ascribe bird species use of these trees as preferred or avoided substrates may be incorrect. Bird species may be restricted, because of competition, to suboptimal habitats (Cody 1974b). For example, in this study tuis were seen successfully defending northern rata trees from bellbirds. Each of the bird species studied showed different tree species preferences and avoidances.

Decrease in foraging niche breadths and overlaps occurs in mixed species flocks in winter (Morse 1970 1978, Hogstad 1978, Alatalo 1980, 1981b). Optimal foraging theory (Pyke et al. 1977) suggests that the individuals in mixed species flocks must be maximising their Darwinian fitness. Morse (1978) has presented a model for prediction of the presumed advantages of mixed species flocking. If overlap in foraging increases then mixed species flocking is food mediated. Factors such as copying the foraging activity of other species and increased flushing of prey will be important. Conversely, if overlap decreases then mixed species flocking may be predator mediated. Overlap in this study decreased in winter. The decrease observed in this study may not be genuine because three of the analysed species were observed in small numbers in at least one season. However, if these three species are excluded from the analysis and the foraging niche overlaps of warblers, whiteheads and riflemen are compared, smallest niche overlaps are still observed in winter. Despite the decrease in niche overlap in winter only one predator species, the falcon, of flying birds existed in the study area. Falcons were rare and did not appear to be a major source of mortality of the birds which congregated in mixed species flocks.

Several explanations are presented for the decreased overlap in foraging niche observed in this study. Firstly, the observed decrease in niche overlap may be an artefact caused by changes in the number of observations of each species in each season. Secondly, species may be constrained in their foraging area in the breeding season because of the need to return to the nest site. This, in conjunction with increased numbers of prey in summer (Moeed and Fitzgerald 1982), may cause birds to increase their foraging breadth within a limited area. Thirdly, the stability of the mixed species flocks observed in winter may be limited. The usual composition of a mixed flock was of large numbers of whiteheads with a few warblers and fantails. Whiteheads form flocks outside the breeding season which are probably food mediated by social facilitation. The species seen in association with these flocks may be present in the same area purely by chance. Or they may be opportunistically taking advantage of the prey flushing by the whitehead flocks into their specialist areas of prey capture. Fantails certainly make use of prey flushing by other species to capture insects in this way. Fourthly, the composition of the avifauna of New Zealand has changed rapidly since the arrival of Polynesians approximately 1000 years ago and precipitously since the arrival of Europeans approximately 200 years ago. The combined effects of habitat modification, predation and competition on native birds have been enormous. Many species have become extinct and of those that have survived many have become localized in distribution or reduced in numbers. The structure of the present day bird community has been strongly influenced by these historical changes and observed interactions may be in a transition state. Fifthly, the model may be too simplistic. Morrison et al. (1987) have noted several factors that are important in understanding the mechanisms of flock formation. Flock formation in their study area did not support the foraging-efficiency or anti-predation model. They concluded that the models could not be tested in the field and that the individuals which make up mixed species flocks were influenced by ecological, evolutionary, and physiological constraints which could differ for different species. A more detailed evaluation of mixed species flocking is required.

Direct comparisons of foraging niches of conspecifics in my study area with Australian observations were confounded because of radically different forest compositions. Tree species usage and foraging height could not be compared. In my study (ground station observations only) fantails were observed foraging in the air 78% of the time, this corresponds with the observations of Holmes and Recher (1985) (78%) and Frith (1984) (75%), however I observed less foraging by fantails from foliage (7.7%) than in either of these two studies (14% and 19.9% respectively). Recher and Holmes (1985) observed silvereyes foraging on foliage (41%), branches (27%), flowers (25%) and the ground (5%) whereas I observed them foraging (ground station observations only) foliage (57.7%), twigs (21.4%), branches (15.3%) and fruit (4.8%).

The habitat use of the birds in this study was compared with other studies carried out in New Zealand (Table 3.6). The variability between studies implies that birds change their feeding strategies in different habitats and communities. Gill (1980) studied a South Island bird community, Gibb (1961) a mainland North Island bird community in exotic (Pinus) forest and Gravatt (1971) an offshore island North Island bird community. The lower proportion of feeding on the ground by tomtits in my study was probably a reflection of the heavy ground cover in much of the study area, which obstructed ground observations.

TABLE 3.6

Comparisons of New Zealand bird species foraging site utilisations between studies

		Gibb 1961	Gravatt 1971	Gill 1980	this study
Warbler	Foliage	78	63.1	82	72.2
	Twig		31.3 *	12	21.5
	Branch	11	2.3	3	5.8
Whitehead	Foliage	71	39.6		7.6
	Twig		24.2		50.2
	Branch	24	22.9		38.2
	Trunk	6	12.7		4.0 **
Silvereye	Foliage	89		34	57.7
	Twig			9	21.4
	Branch	6		6	15.3
	Trunk	0		42	0.4
Rifleman	Twig		8.4		11.9
	Branch		24.2		52.0
	Trunk		62.1		34.4 **
Tomtit	Ground	60	52.4		37.7
	Foliage	14	17.9		4.3
	Twig		5.6 *		18.1
	Branch	8	13.7		21.7
	Trunk	12	6.1		18.1

* = twigs and terminal shoots ** = trunks and limbs

All data in percentages.

In the exotic forest whiteheads and silvereyes were observed using foliage much more than in native forest. The degree of overlap in foraging site between species in these studies was greater than in the present study. Forest composition and structure varied markedly in each study as did the composition of the bird community. Further studies are needed to determine the degree of plasticity in foraging niches, and to examine how this variability relates to changes in community structure.

Moeed and Fitzgerald (1982) have demonstrated that the use of foliage and fruit of mainly insectivorous birds in New Zealand may have been underestimated. They examined the faeces of different bird species in forest of the Orongorongo Valley, 70Kms. southeast of my study area. All species had some vegetation in their faeces in at least one season. Furthermore, the proportion of insect prey items in warblers and tomtits were similar, although they used markedly different substrates for foraging. Beetles were the most important prey item for all the insectivorous species except fantails, in which flying insects (flies, moths and wasps) were most important. They found little variation in the frequency of consumption of main foods throughout the year. Seasonal changes in feeding sites in my study may reflect changes in the distribution of prey species.

The observed differences in bird foraging niches between studies within New Zealand indicate that birds respond quite rapidly to changes in both habitat and composition of the bird community. The plasticity of foraging niches within New Zealand means that little can be concluded from the differences in foraging substrate use by conspecifics in New

Zealand and Australia. The ability to rapidly change foraging niche may partially explain the limited number and density of introduced species which have invaded the native forest of my study area. Another explanation may be that the majority of introduced species are birds of open country. None of the Parus tits, the majority of which are forest dwelling species, have been introduced.

It is interesting to look at which species of introduced birds have succeeded in invading the forest, and how these relate to birds which have become extinct or reduced in numbers. Blackbirds and thrushes forage mainly on the ground, in my study they were observed foraging exclusively on the ground. It is not surprising that they have successfully invaded the forest because most of the native birds which fed on the forest floor were highly susceptible to predation by introduced mammals. Birds in this category, which were common in the area, are robins, New Zealand thrushes and wekas (Buller 1888, Wilkinson 1924). Of the remaining native birds within the study area only tomtits forage on the ground. Tomtits are much smaller in size, and have a different foraging strategy, than both blackbirds and thrushes indicating that they consume different prey. Dunnocks were resident only in the scrub and tussock of the highest altitude stations. I did not observe any foraging behaviour, but they forage mainly on the ground (Bull 1985b), as such it is likely that they have also taken advantage of the removal of the ground dwelling native avifauna.

Chaffinches and silvereyes were both observed foraging on a wide variety of substrates and tree species. Both species are generalist gleaners, foraging mainly from foliage. It is probable that they compete for food with warblers and whiteheads, silvereyes also compete for nectar resources with tuis and bellbirds. Chaffinches have not replaced any of the native species which have been removed. It is significant that chaffinches appear to enter the forest during the breeding season and leave during the non-breeding season this entry into the study area in times of probable food abundance and absence in periods of food shortage allows them to avoid competition with the native avifauna. The resources that silvereyes use are similar to those used by stitchbirds (Gravatt 1971), which may partly explain the extent of their invasion into the forest.

The native species which have been replaced by introduced birds became rare or extinct in the study area before the advent of the introduced bird species (Buller 1888, Wilkinson 1924). Those native birds which have become extinct were susceptible to changes associated with human colonisation (Holdaway 1989), and the introduced birds took advantage of the resources which the native birds had used. In conclusion, the introduced species did not displace the natives which they have replaced. Further research, in different areas, is needed to compare the integration of the introduced species with the natives and to determine how successful they are at invading habitats in which different native birds have survived.

CHAPTER 4

SYNTHESIS

In this synthesis the management implications of the study are discussed. Bird distributions, abundances and foraging niches are considered concurrently and related to ecological theories.

It is simplistic to suggest that the composition of forest bird communities is dictated solely by vegetational features of the environment. Climate and topography affect the entire biota and, together with competition (Roughgarden 1983), history (Koen and Crowe 1987) and size or shape of the forested area (Soule and Simberloff 1986), are important in structuring bird communities. Because of the interaction of these factors, bird species abundance in different areas cannot be directly correlated with the presence of particular tree species. Nevertheless, knowledge of bird species/tree species inter-relationships should be valuable in managing forests for conservation of particular bird populations. Multivariate analyses suggest that there are several broad categories of forest type with which differing bird communities are associated. These associations may simplify forest management because one type of forest supports a number of bird species.

The distribution of birds, and their preferences for particular tree species as foraging substrates, indicate what types of forest should be conserved for those birds. High-canopy mixed podocarp broadleaf forest with rimu, miro, kamahi, with some nectar resources (in this study Metrosideros), appear to favour high densities of whiteheads, riflemen, tomtits, pigeons and tuis. Whereas high-canopy red beech-dominated forest with toro as a component of the understorey apparently favours fantails, warblers, chaffinches, silvereyes and blackbirds. However, the forest preferences of birds within my study area must also be considered in relation to the surrounding habitat. The red-beech dominated forest was adjacent to surrounding farmland and the Mangatainoka River. The large proportion of introduced birds in red-beech forest may be a reflection of the nearness of pastureland. In addition, comparison with other studies in New Zealand revealed that native forest birds show great variations in their foraging niches between areas.

I found that the bird species composition of the study area was related to both the forest structure and the plant species community. Of the niche dimensions investigated foraging site displayed the greatest difference between species followed by tree species and foraging height. However, comparisons with other studies demonstrated that there is a large degree of plasticity in foraging sites between habitats. The birds utilised tree species in significantly different proportions from what was available. These findings support the hypothesis of Holmes and Recher (1986b) that "vegetation structure coupled with food resource availability and abundance, provide particular combinations of foraging opportunities for birds that in turn determine which birds can forage successfully and survive there." Foliage structure and resource availability vary with both plant species and tree height. These factors shape the foraging opportunities available to birds, which in turn influence which species can successfully exploit food there, and so can be considered primary determinants of guild structure (Holmes and Recher 1986b). It is a measure of the resilience of this hypothesis that it can be applied to the highly disturbed environment of my study area. Although the hypothesis is widely applicable it does not apply to all bird communities. Koen and Crowe (1987) studied the bird communities of podocarp forests in southern Cape Province, South Africa. They observed similar bird communities in structurally and floristically different forests and concluded that historical and biogeographic factors in conjunction with low nutrient soils may have been important in determining the structure of the bird communities.

High foraging niche breadth or foraging niche overlap in one axis was not compensated for by low values for other axes in my analysis. There was a decrease in foraging niche overlap in winter in conjunction with mixed species flocking. Changes in birds' foraging niches between studies indicated a remarkable degree of plasticity. These findings present conflicting information as to the importance of competition in structuring the bird community. The reduced foraging niche breadths and overlaps in winter support the hypothesis of Schoener (1982) for niche contraction in periods of food shortage as a result of competition. The differences in bird foraging niches between studies within New Zealand indicate that birds are competitively constrained by the bird community composition, although differences in habitat may also be important. The small degree of foraging niche overlap between species also supports the hypothesis that competition is important in structuring the bird community. However, the lack of complementarity in foraging dimensions argues against the presence of competition, although Alatalo (1982) has criticised this concept. It is probable that interspecific competition occurs more often in moderate environments in the absence of extreme physical conditions which reduce populations below the carrying capacity of their environment (Connell 1980), so the study area is likely to be a competitive environment. The only interspecific aggressive interactions observed were between the three nectar-feeding species. The importance of competition in structuring the forest bird community is strongly indicated but cannot be verified without experimental manipulation.

Birds in the study area had surprisingly narrow niche breadths. Both niche breadths and niche overlaps were comparable with much richer bird species assemblages. Because of differences in forest composition, comparison of the foraging niches of conspecifics in the study area and Australia were difficult. Differences in foraging substrate utilisation between studies within New Zealand were comparable to differences between Australia and New Zealand. These observations disagree with the predictions of the theory of island biogeography (MacArthur and Wilson 1967, Diamond 1970). Narrow niche breadths may be an adaptation to a moderate predictable environment (Levins 1968). Moeed and Fitzgerald (1982) noted that there is a relatively small increase in invertebrate prey availability in summer in similar forest to that of my study area. These observations indicate that the niche breadths of insectivorous birds in my study area may be comparatively narrow because the moderate environment combined with an evergreen forest result in relatively stable food resources.

Analysis of the foraging niches and abundances of introduced birds within the study area reveal that they make up a relatively small fraction of the forest avifauna considering the large number of extinctions caused by introduced mammals. The introduced birds generally used resources which would have been used by native species had they been present. All of the introduced birds were most abundant on the edges of the forest where habitat modification is greatest. Silvereyes and chaffinches moved into and out of the study area at different times of the year, allowing them to take advantage of peaks in resource availability and so avoid competition with native species. The changes in native bird foraging niche between forest habitats in New Zealand indicate that they can rapidly alter their foraging niches in response to changes in habitat and bird community. This plasticity of foraging niche combined with the small number of introduced birds which are forest inhabiting species may explain why so few introduced species have successfully invaded New Zealand native forests.

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APPENDIX 1

Tree species surrounding each station by tier

Canopy tier

Tree species code (scientific names in table 1.1)

STATION	RIMU	MIRO	HALL	PHYL	RBEE	RATA	KAMA	MAHO	TORO	BRDL	HINA	PUTA	AXIL	COLO	CFOE	CPOL	OLEC	DFIL	TFER	OTHER	MISSING
1	0	0	0	0	94	0	9	4	0	1	0	1	0	0	0	0	0	0	8	3	0
2	0	0	0	0	94	0	13	1	0	0	0	2	2	0	0	0	0	0	0	8	0
3	0	0	2	0	26	0	56	15	3	0	1	8	0	0	0	0	0	0	6	3	0
4	0	0	0	0	49	0	25	3	7	0	0	6	0	0	0	0	0	0	21	9	0
5	7	1	0	0	68	0	32	0	1	1	0	2	0	0	0	0	0	0	8	0	0
6	0	0	0	0	75	0	25	2	2	4	1	1	0	0	0	0	0	0	8	2	0
7	0	0	0	0	50	0	40	1	6	3	0	8	0	0	0	0	0	0	10	2	0
8	1	1	0	0	70	0	35	6	0	0	0	0	0	0	0	0	0	0	7	0	0
9	2	22	8	1	0	0	67	0	15	1	0	0	0	0	3	0	0	0	0	1	0
10	25	3	4	0	37	0	27	0	11	3	4	5	0	0	0	0	0	0	1	0	0
11	4	8	0	0	3	0	54	0	36	0	3	1	0	0	0	0	0	0	9	2	0
12	51	21	0	0	0	0	44	0	4	0	0	0	0	0	0	0	0	0	0	0	0
13	13	3	0	0	3	0	55	2	0	8	4	11	0	0	0	0	0	0	21	0	0
14	5	25	0	0	0	0	66	1	7	2	4	5	0	0	0	0	0	0	3	2	0
15	23	22	0	0	0	0	68	0	1	0	5	0	0	0	0	0	0	0	0	1	0
16	16	3	0	0	18	0	59	4	1	7	6	6	0	0	0	0	0	0	0	0	0
17	2	1	0	0	81	0	26	0	0	0	0	0	0	0	0	0	0	0	0	0	10
18	2	22	0	0	45	0	37	0	0	0	9	0	3	0	0	0	0	0	0	2	0
19	22	31	0	0	2	0	45	0	11	0	5	0	0	0	0	0	0	0	0	4	0
20	31	39	0	4	10	0	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	20	10	0	3	48	0	30	0	8	0	0	0	0	0	0	0	0	0	0	1	0
22	25	2	7	14	0	0	62	0	10	0	0	0	0	0	0	0	0	0	0	0	0
23	6	5	1	15	34	0	53	0	6	0	0	0	0	0	0	0	0	0	0	0	0
24	10	0	11	15	9	0	61	0	2	0	0	0	0	0	1	2	0	2	0	7	0
25	18	8	5	17	0	0	63	0	8	1	0	0	0	0	0	0	0	0	0	0	0
26	8	7	14	16	0	0	66	0	5	1	0	0	0	0	1	0	0	1	0	1	0
27	19	2	1	22	24	0	51	0	0	0	0	0	0	0	0	0	0	0	0	1	0
28	1	0	11	8	1	0	73	0	9	13	0	0	0	0	1	1	0	0	1	1	0
29	0	0	2	32	5	0	43	0	0	0	0	0	0	0	2	2	0	8	0	26	0
30	0	0	4	1	16	0	65	0	29	0	0	0	0	0	0	2	0	0	0	3	0
31	1	3	11	17	0	0	76	0	7	4	0	0	0	0	0	0	0	1	0	0	0
32	0	3	14	2	5	0	81	0	12	2	0	1	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	80	0	19	5	0	1	0	0	0	0	0	0	0	0	15
34	4	0	0	0	0	0	81	0	25	0	0	4	0	0	0	0	0	0	1	5	0
35	3	1	2	0	0	0	78	2	7	7	2	10	0	0	0	0	0	0	4	4	0
36	6	0	1	0	0	0	71	4	24	7	0	1	0	0	0	0	0	0	0	6	0
37	10	2	0	0	0	0	92	0	3	7	2	1	0	1	0	0	0	0	0	2	0
38	5	1	7	0	0	0	94	0	13	0	0	0	0	0	0	0	0	0	0	0	0
39	6	0	1	3	0	0	67	0	34	3	0	0	3	0	0	2	0	0	0	1	0
40	4	3	1	0	0	0	99	0	5	0	8	0	0	0	0	0	0	0	0	0	0
41	0	6	5	0	0	0	71	0	27	0	0	0	0	1	0	0	0	0	0	0	10
42	0	1	17	4	0	0	67	0	12	6	0	0	0	1	2	0	3	0	0	7	0
43	1	0	2	7	0	0	38	0	0	4	0	0	0	5	10	0	24	4	0	25	0
44	0	0	2	5	0	0	11	0	0	4	0	0	0	7	8	1	56	4	0	22	0
45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	51	40	0	27	0
46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	83	30	0	6	0
47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	83	19	0	18	0
48	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	49	0	0	69	0

Appendix 1 continued

Subcanopy tier

Tree species code (scientific names in table 1.1)

STATION	RIMU	MIRO	HALL	PHYL	RBEE	RATA	KAMA	MAHO	TORO	BRDL	HINA	PUTA	AXIL	COLO	CFOE	CPOL	OLEC	DFIL	TFER	OTHER	MISSING
1	0	0	0	0	12	0	66	11	0	0	0	5	0	0	0	0	0	0	0	6	20
2	0	0	0	0	36	0	53	5	0	0	3	7	0	0	0	0	0	0	4	7	5
3	0	0	0	0	3	1	16	18	5	1	0	1	11	0	0	0	0	0	63	1	0
4	0	2	0	0	16	0	7	8	3	1	0	6	6	0	0	0	0	0	31	11	29
5	0	3	0	0	33	0	37	4	10	1	3	7	2	0	0	0	0	0	11	4	5
6	0	1	0	0	30	0	29	1	16	0	0	8	10	0	0	0	0	0	16	4	5
7	0	0	0	0	23	0	24	5	21	0	0	6	5	0	0	0	0	0	24	12	0
8	0	1	0	0	11	0	40	3	22	1	2	2	11	0	1	0	0	0	24	2	0
9	3	11	4	0	0	0	18	0	59	0	0	0	0	0	4	0	0	0	2	2	17
10	0	7	1	4	2	0	20	0	75	0	3	2	4	0	0	0	0	0	2	0	0
11	4	0	3	1	0	0	14	1	52	0	0	1	19	0	0	0	0	0	11	0	14
12	2	11	2	0	0	0	33	3	55	0	0	0	4	0	0	1	0	0	1	6	2
13	0	3	0	0	0	0	9	7	38	0	1	4	3	0	0	0	0	0	35	0	20
14	2	4	0	0	0	0	19	5	42	0	1	2	4	0	0	0	0	0	30	1	10
15	0	8	0	0	0	0	66	0	30	0	1	2	10	0	0	0	0	0	1	2	0
16	0	6	1	0	11	0	49	17	8	1	1	8	1	0	0	0	0	0	15	2	0
17	0	8	0	0	15	0	53	0	21	0	1	1	2	0	0	0	0	0	3	1	15
18	0	2	0	0	20	0	45	4	15	0	2	1	9	0	0	0	0	0	7	0	15
19	2	10	1	0	2	0	59	0	29	2	2	0	8	0	0	0	0	0	0	2	3
20	4	20	3	10	0	0	38	0	43	0	0	0	0	0	0	0	0	0	0	2	0
21	0	0	0	6	3	0	21	0	76	0	0	3	1	0	0	0	0	0	5	0	5
22	0	14	22	4	0	0	12	0	58	0	0	0	0	0	0	0	0	0	0	0	10
23	0	7	12	3	0	0	52	0	40	0	0	0	0	0	0	0	0	0	0	1	5
24	1	0	7	6	1	0	20	0	9	0	0	0	0	0	0	2	0	0	0	1	73
25	0	5	18	0	0	0	29	0	32	0	0	0	0	0	0	0	0	0	0	5	31
26	0	6	2	0	0	0	11	0	44	0	0	2	0	0	0	0	0	0	0	3	52
27	3	3	20	7	0	0	58	0	15	0	0	0	0	0	0	0	0	0	0	4	10
28	0	0	7	0	0	0	1	0	6	0	0	0	0	0	0	0	0	0	0	0	106
29	0	0	0	3	0	0	2	0	0	0	0	0	0	0	0	0	0	1	0	3	111
30	0	0	4	0	0	0	21	0	75	0	0	0	0	0	0	0	0	0	0	0	20
31	0	2	7	1	0	0	23	0	66	0	0	0	0	7	0	0	0	0	0	2	12
32	0	1	10	0	0	0	1	0	105	0	0	2	0	1	0	0	0	0	0	0	0
33	0	0	2	0	0	0	16	0	69	2	0	1	1	11	0	0	0	0	0	3	15
34	2	0	6	0	0	0	20	7	58	0	0	0	2	2	0	0	0	0	0	3	20
35	4	6	4	0	0	0	11	4	57	0	0	2	2	8	0	0	0	0	7	0	15
36	2	1	0	0	0	0	16	6	73	1	0	1	4	8	0	0	0	0	1	2	5
37	0	4	0	0	0	0	15	2	74	0	0	2	10	7	0	0	0	0	3	3	0
38	1	3	7	0	0	0	18	0	25	1	0	0	0	0	0	3	0	0	0	0	62
39	0	6	1	1	0	0	10	0	79	0	0	0	10	0	0	0	0	0	1	5	7
40	0	0	5	0	0	0	11	0	69	0	1	1	23	0	0	1	0	0	1	0	8
41	0	0	6	1	0	0	16	0	67	0	0	0	0	8	1	0	0	0	0	2	19
42	0	6	7	0	0	0	3	0	53	0	0	0	0	11	0	0	0	0	0	0	40
43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	120
44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	120
45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	120
46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	120
47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	120
48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	120

Appendix 1 continued

Shrub tier

Tree species code (scientific names in table 1.1)

STATION	RIMU	MIRO	HALL	PHYL	RBEE	RATA	KAMA	MAHO	TORO	BRDL	HINA	PUTA	AXIL	COLO	CFOE	CPOL	OLEC	DFIL	TFER	OTHER	MISSING
1	0	1	0	0	5	0	55	1	0	1	0	11	3	0	0	2	0	0	5	36	0
2	0	0	0	0	6	0	10	3	2	0	1	8	8	0	0	1	0	0	15	66	0
3	0	6	0	0	2	2	1	0	2	0	0	0	45	0	0	0	0	0	57	5	0
4	0	2	0	0	2	6	4	3	0	4	0	0	21	1	0	0	0	0	57	17	3
5	0	9	0	0	13	4	7	0	26	1	5	2	7	0	6	19	0	0	14	7	0
6	2	12	0	0	13	0	28	0	5	3	4	6	11	0	2	2	0	0	22	10	0
7	2	6	0	0	6	1	7	1	9	1	1	24	5	0	2	8	0	0	20	27	0
8	1	21	0	0	0	2	14	0	0	1	2	1	17	0	2	0	0	0	44	15	0
9	3	5	20	26	0	0	1	0	15	0	0	0	3	0	9	13	0	0	1	24	0
10	3	16	9	3	3	0	1	0	31	0	1	0	13	0	0	19	0	0	20	1	0
11	8	23	5	1	0	2	3	0	18	0	1	1	24	0	1	1	0	0	14	7	11
12	0	5	10	21	0	0	1	1	15	0	4	0	12	0	5	40	0	0	3	3	0
13	11	10	9	0	0	0	3	0	5	1	0	3	14	0	1	11	0	0	46	1	5
14	3	7	3	0	0	11	0	1	4	1	0	1	4	0	10	18	0	0	54	3	0
15	3	15	6	0	3	0	11	0	6	1	1	4	17	0	5	24	0	0	20	4	0
16	0	5	1	0	13	0	3	1	1	0	1	3	5	1	7	27	0	0	50	2	0
17	0	10	0	0	1	0	7	0	5	1	3	3	3	0	13	10	0	0	1	43	20
18	1	8	1	0	1	0	3	1	6	0	9	10	27	0	0	9	0	0	22	22	0
19	6	12	6	0	0	1	8	0	7	1	14	0	20	0	4	27	0	0	0	14	0
20	0	14	13	18	0	0	1	0	15	0	7	0	0	0	6	38	0	0	0	8	0
21	4	6	10	10	10	0	2	0	17	0	0	1	1	1	8	36	0	4	5	5	0
22	3	10	18	9	0	0	0	0	11	0	0	0	0	0	19	43	0	0	0	7	0
23	0	10	16	1	0	0	1	0	2	1	0	0	0	0	21	56	0	0	2	10	0
24	6	8	24	2	0	0	1	0	0	0	0	0	0	1	6	65	0	0	0	2	5
25	0	1	6	1	0	0	0	0	4	0	0	0	0	0	13	65	0	2	0	28	0
26	0	11	29	1	0	0	2	0	15	0	0	0	0	1	3	48	0	0	5	5	0
27	0	2	12	1	0	0	3	0	4	0	0	0	0	0	11	75	0	0	0	12	0
28	6	7	38	8	2	0	0	0	2	0	0	0	1	16	4	30	0	0	0	4	2
29	0	1	21	5	0	0	4	0	0	0	0	0	0	0	10	59	1	4	0	10	5
30	0	3	5	3	2	0	0	0	20	0	0	0	0	6	7	69	0	0	2	3	0
31	1	3	2	1	0	0	0	0	9	0	0	0	0	23	6	63	0	0	6	6	0
32	2	7	10	1	3	0	1	0	42	1	0	0	4	14	5	26	0	0	1	3	0
33	0	3	3	0	0	1	0	1	1	0	0	0	0	20	6	25	0	0	28	17	15
34	3	7	5	0	0	0	0	0	1	0	0	7	2	19	2	29	0	0	38	7	0
35	4	2	2	0	0	0	0	0	2	0	0	1	4	25	3	47	0	0	20	5	5
36	2	3	8	0	0	0	2	1	5	0	0	0	4	29	4	19	0	0	35	8	0
37	2	4	3	0	0	0	0	0	0	0	0	0	18	11	0	19	0	0	40	23	0
38	1	2	18	9	0	0	1	0	0	0	0	0	1	0	0	82	0	0	0	6	0
39	3	8	14	1	0	2	2	0	16	0	0	0	9	4	3	42	0	0	12	4	0
40	5	8	14	0	0	0	0	0	3	0	0	0	28	1	0	18	0	0	24	19	0
41	0	2	6	1	0	0	2	0	5	0	0	0	1	27	31	16	0	0	0	19	10
42	1	1	10	2	0	0	4	0	13	0	0	0	0	47	9	8	7	0	0	13	0
43	0	1	8	0	0	0	4	0	2	1	0	1	0	34	14	20	4	1	1	34	0
44	0	0	4	5	0	0	2	0	0	1	0	0	0	10	8	31	4	4	0	38	13
45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	120
46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	120
47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	117
48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	115

Appendix 1 continued

Ground tier

Tree species code (scientific names in table 1.1)

STATION	RIMU	MIRO	HALL	PHYL	RBEA	RATA	KAMA	MAHO	TORO	BRDL	HINA	PUTA	AXIL	COLO	CFOE	CPOL	OLEC	DFIL	TFER	OTHER	MISSING
1	0	1	0	0	61	0	2	2	0	3	1	4	8	0	0	5	0	0	0	33	0
2	0	0	0	0	11	0	14	11	1	5	3	4	1	1	2	2	0	0	0	65	0
3	0	0	0	0	2	4	0	1	1	29	8	3	19	0	0	0	0	0	0	53	0
4	0	0	0	0	1	23	7	3	0	28	0	7	8	1	1	0	0	0	0	41	0
5	0	6	0	0	3	21	10	2	11	31	0	1	4	1	4	10	0	0	0	16	0
6	0	8	0	0	1	0	33	0	12	9	5	1	9	0	0	0	0	0	0	42	0
7	0	1	0	0	12	9	11	8	4	8	2	13	0	0	3	2	0	0	0	47	0
8	0	7	0	0	2	14	10	0	2	20	4	1	3	0	1	0	0	0	0	56	0
9	0	8	1	2	0	2	1	0	30	8	0	0	0	0	33	8	0	0	0	27	0
10	0	19	0	2	2	0	7	0	45	11	5	0	6	4	2	9	0	0	0	8	0
11	6	16	1	0	0	10	14	1	7	13	3	2	5	0	0	1	0	0	0	41	0
12	1	15	1	3	0	8	5	0	16	8	4	0	2	3	6	36	0	0	0	12	0
13	2	15	0	1	0	0	5	3	11	35	1	18	3	7	3	3	0	0	2	11	0
14	0	10	0	0	0	26	4	0	17	17	18	2	2	2	1	5	1	0	0	15	0
15	1	19	2	4	0	0	4	0	28	17	12	1	0	1	11	11	0	0	0	9	0
16	0	5	1	0	1	0	5	6	15	21	10	8	1	1	11	10	0	0	2	23	0
17	0	6	0	0	3	0	4	2	3	25	1	0	0	1	4	18	0	0	2	31	20
18	0	15	0	0	1	0	6	4	8	20	22	3	5	3	1	4	0	0	0	28	0
19	0	12	1	0	0	2	6	1	21	15	12	1	7	0	5	4	0	0	0	33	0
20	0	23	1	1	1	0	1	0	26	7	5	1	3	3	7	28	0	0	0	13	0
21	2	28	0	2	12	0	2	0	20	12	0	0	0	0	20	14	0	0	0	8	0
22	0	8	5	5	0	0	0	0	26	0	0	0	0	2	21	40	0	0	0	13	0
23	0	3	7	0	21	0	0	0	27	14	0	0	0	0	14	25	0	0	0	9	0
24	1	0	7	1	13	0	0	0	12	15	0	0	0	1	5	32	0	0	0	33	0
25	0	2	3	3	0	0	2	0	27	12	0	0	0	0	5	32	0	0	0	34	0
26	0	13	8	2	0	0	0	0	15	11	0	0	0	1	14	32	0	0	0	24	0
27	0	5	1	1	30	0	1	0	24	16	0	0	0	1	8	23	0	0	0	10	0
28	0	6	2	5	4	0	0	0	19	12	0	0	0	2	10	25	0	0	0	35	0
29	0	2	0	0	6	0	6	0	5	15	0	0	0	0	14	49	3	1	0	19	0
30	0	3	1	3	12	0	1	0	37	5	0	0	0	0	7	37	0	0	0	13	1
31	0	0	0	1	0	0	0	0	43	13	0	0	1	16	1	24	0	0	0	21	0
32	0	16	9	0	8	0	0	0	18	26	0	0	0	5	11	10	0	0	0	17	0
33	0	1	0	0	0	15	0	4	20	11	0	4	0	8	12	7	0	0	1	22	15
34	0	4	1	0	0	0	2	7	19	22	0	6	1	9	6	22	0	0	2	19	0
35	0	5	0	0	0	0	8	1	37	27	2	7	1	12	4	7	0	0	0	9	0
36	3	6	2	0	0	0	3	14	25	14	0	3	0	10	9	17	0	0	0	14	0
37	0	5	0	0	0	0	2	4	46	26	2	0	0	19	2	5	0	0	0	9	0
38	1	16	0	2	0	5	2	0	27	16	0	0	0	3	6	40	0	0	0	2	0
39	0	7	0	5	0	11	9	0	32	11	0	0	2	7	4	20	0	0	0	12	0
40	0	15	0	0	0	11	0	0	45	6	5	0	6	0	0	16	0	0	5	11	0
41	0	1	2	0	0	0	10	1	25	11	0	1	0	9	20	13	1	0	0	16	10
42	0	1	3	0	0	0	3	0	11	19	0	0	0	6	26	22	0	0	0	29	0
43	0	0	0	0	0	0	5	0	0	23	0	0	0	33	6	13	4	0	0	36	0
44	0	0	0	0	0	0	1	0	0	28	0	0	0	9	6	23	11	3	0	34	5
45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	5	78	15	0	20	0
46	0	0	0	0	0	0	1	0	0	0	0	0	0	0	4	0	89	10	0	16	0
47	0	0	0	0	0	0	0	0	0	1	0	0	0	0	4	0	10	0	0	16	89
48	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2	0	0	22	95

APPENDIX 2

Number of tree species point height intercepts at each station

Tree species code (scientific names in table 1.1)

STATION	RIMU	MIRO	HALL	PHYL	RBEE	RATA	KAMA	MAHO	TORO	BRDL	HINA	PUTA	AXIL	COLO	CFOE	CPOL	OLEC	DFIL	TFER	OTHER
1	0	0	0	0	63	0	23	2	0	1	0	2	0	0	0	0	0	0	4	5
2	0	0	0	0	52	5	25	4	0	0	0	0	0	0	0	0	0	0	5	23
3	0	0	0	0	25	5	50	9	12	4	6	2	8	0	0	0	0	0	30	48
4	0	0	0	0	30	8	21	3	1	0	0	3	5	0	0	0	0	0	26	39
5	1	0	0	0	73	1	50	0	0	1	0	1	0	0	0	2	0	0	2	3
6	0	3	0	0	55	0	31	0	6	0	3	1	5	0	0	0	0	0	12	16
7	0	1	0	0	42	0	26	0	4	0	0	1	1	0	0	2	0	0	16	27
8	0	4	0	0	77	2	46	1	14	0	0	3	4	0	2	0	0	0	15	17
9	4	26	3	4	0	0	55	0	8	0	0	0	0	0	0	0	0	0	0	1
10	9	9	0	8	27	0	41	0	33	2	0	0	0	0	0	0	0	0	1	2
11	1	2	0	0	1	1	88	0	26	0	0	3	4	0	0	0	0	0	3	4
12	6	31	1	2	0	1	45	0	7	3	0	0	3	0	1	2	0	0	0	2
13	9	3	0	0	4	2	45	14	11	4	0	1	2	0	0	0	0	0	17	25
14	0	27	0	0	3	4	61	1	8	1	0	3	0	0	0	1	0	0	4	6
15	6	17	0	0	0	5	92	0	0	0	0	0	4	0	0	0	0	0	3	3
16	4	0	0	0	24	3	62	6	0	0	0	2	0	0	0	0	0	0	15	15
17	0	0	0	0	75	0	34	0	2	1	0	0	0	0	0	0	0	0	0	2
18	1	27	0	0	67	4	53	0	0	1	6	0	6	0	0	0	0	0	4	9
19	13	47	1	0	0	6	23	0	1	0	0	0	8	0	1	0	0	0	0	10
20	6	37	1	4	15	0	46	0	13	0	0	0	0	0	1	0	0	0	0	0
21	1	1	1	3	23	0	36	0	27	0	0	0	0	0	6	0	0	0	1	1
22	22	2	4	7	0	0	43	0	25	0	0	0	0	0	0	1	0	0	0	0
23	4	4	2	6	26	0	59	0	5	0	0	0	0	0	0	2	0	0	0	0
24	4	0	1	12	4	0	63	0	3	0	0	0	0	0	0	2	0	0	0	12
25	45	43	26	7	0	0	56	0	38	2	0	0	0	4	2	17	0	0	0	1
26	13	19	10	9	0	0	52	0	11	3	0	0	0	0	0	1	0	0	0	0
27	0	4	0	19	18	0	38	0	8	0	0	0	0	0	0	3	0	0	0	9
28	0	0	3	3	0	0	81	0	2	13	0	0	0	1	0	2	0	0	0	2
29	0	0	1	27	1	0	56	0	1	0	0	0	0	0	1	7	0	0	0	26
30	0	0	1	0	16	0	44	0	20	0	0	0	0	0	0	14	0	0	0	12
31	14	9	9	14	0	0	85	0	72	2	0	0	0	8	2	53	0	0	1	7
32	0	5	8	1	10	0	54	0	19	0	0	0	0	0	0	5	0	0	0	0
33	0	0	1	0	0	7	59	0	18	2	0	2	0	8	0	1	0	0	9	22
34	6	1	1	0	0	20	68	3	23	0	0	2	0	1	0	0	0	0	10	20
35	4	5	2	0	0	0	57	0	17	4	10	3	12	1	0	3	0	0	2	2
36	0	0	2	0	0	2	64	2	16	5	0	4	0	2	0	0	0	0	11	14
37	5	6	0	0	0	1	76	0	23	0	0	0	2	0	0	0	0	0	5	5
38	4	5	4	4	0	0	83	0	7	0	0	0	0	0	0	1	0	0	0	0
39	10	7	3	0	0	2	89	0	16	2	2	0	5	0	0	0	0	0	2	4
40	4	0	1	0	0	1	72	0	14	0	0	0	11	0	0	1	0	0	4	4
41	2	6	14	0	0	0	49	0	26	2	0	0	0	17	4	6	0	0	1	1
42	0	10	20	0	0	0	43	0	19	4	0	0	0	13	3	5	5	0	0	9
43	0	0	0	0	0	0	36	0	0	1	0	0	0	3	16	0	20	0	0	42
44	0	0	2	5	0	0	8	1	0	1	0	0	0	6	8	0	30	0	0	59
45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	0	0	61
46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35	0	0	82
47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26	0	0	50
48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	2	0	35

APPENDIX 3

Structural parameters of the vegetation at each station

STATION	XCAN	PD1	PD2	PD3	DBH1	DBH2	DBH3	WID1	WID2	WID3
1	18.08	928.5	991.08	1076.3	25.3	7.7	2.7	5.9	2.4	1.2
2	13.83	983.0	1568.63	2419.6	25.3	8.5	3.6	5.8	2.8	0.9
3	12.30	699.6	1048.77	2106.6	42.0	13.8	6.2	6.0	3.5	1.3
4	12.31	795.5	998.60	2185.8	28.8	10.8	7.1	6.1	3.2	1.7
5	19.99	973.0	1492.09	2862.0	55.4	9.1	2.9	8.7	3.1	0.8
6	14.37	1174.8	1274.70	2558.2	17.7	8.1	4.4	7.1	3.3	1.4
7	14.90	1005.1	1174.95	3915.4	39.4	12.6	3.4	6.0	3.3	1.1
8	20.01	1182.6	1234.42	3066.5	36.6	9.9	4.6	10.2	3.6	1.5
9	11.44	1155.7	1086.48	3425.8	25.3	7.7	1.6	5.1	2.2	0.6
10	15.84	919.7	1931.62	2167.8	61.2	9.2	3.8	7.9	2.3	0.9
11	13.06	1056.3	2617.12	3328.9	24.7	8.1	5.1	7.0	2.8	1.6
12	17.27	1041.7	976.66	3672.4	36.8	11.9	1.5	6.9	4.0	0.9
13	9.97	833.5	856.24	1097.1	47.4	14.6	5.5	6.8	3.2	1.1
14	10.95	912.4	633.07	1511.9	30.8	13.6	4.8	4.4	2.7	0.9
15	15.24	816.4	681.80	1167.5	44.4	12.4	1.7	6.2	3.8	0.6
16	11.87	803.5	486.36	1252.0	48.6	11.2	7.2	7.0	3.8	1.4
17	16.21	584.1	650.28	3554.9	56.4	11.8	2.0	9.0	3.4	0.6
18	13.16	650.5	693.05	2594.7	59.8	10.5	3.7	8.0	2.9	0.8
19	16.57	783.4	859.92	5449.6	36.6	10.0	1.9	7.4	3.6	1.0
20	13.06	1073.8	804.05	7485.0	42.5	9.9	0.9	6.3	3.0	0.5
21	12.54	1277.6	3287.31	12269.9	40.8	7.3	1.4	5.8	2.5	0.5
22	9.15	1326.3	1248.60	10857.8	22.1	8.2	1.3	4.7	2.7	0.4
23	11.53	991.0	828.09	2427.8	34.8	12.0	1.1	5.8	2.9	0.3
24	6.77	1522.8	430.22	5168.0	23.2	10.1	1.2	4.3	2.6	0.5
25	6.37	1570.6	428.61	18281.5	15.4	10.4	0.9	3.3	2.3	0.3
26	7.85	1746.1	890.71	10193.7	26.3	7.8	1.5	4.4	2.8	0.7
27	9.50	913.0	751.71	10449.3	25.8	11.2	0.9	4.8	2.6	0.5
28	6.30	1597.4	407.61	5385.0	18.6	8.2	1.6	5.1	2.6	0.8
29	4.78	2559.5	390.53	9460.7	10.7	8.7	0.9	2.7	2.1	0.5
30	9.37	889.7	1614.73	14903.1	22.1	7.0	2.4	4.8	2.6	0.6
31	7.25	1587.3	388.67	7215.0	22.0	8.8	2.2	4.3	3.1	0.6
32	11.74	1132.9	2043.74	8976.7	26.9	6.2	1.6	6.7	2.7	0.8
33	9.43	703.7	700.28	8223.7	28.8	11.1	5.2	4.9	2.7	1.0
34	8.96	1017.0	998.70	3897.1	35.9	11.1	2.8	5.9	2.7	0.8
35	7.43	988.8	922.51	5257.6	29.8	11.4	3.6	4.7	2.7	1.3
36	9.52	859.1	792.39	5073.6	35.5	9.0	3.6	5.1	2.4	0.9
37	12.28	597.1	1032.10	2624.0	47.3	9.9	4.8	9.8	2.6	1.2
38	8.85	1066.9	903.10	9587.7	18.9	7.9	1.2	4.0	2.0	0.6
39	10.47	873.1	1090.16	4885.2	35.1	9.1	3.8	5.3	2.1	0.8
40	11.68	655.3	858.59	2850.6	33.1	6.9	3.9	6.2	1.9	0.9
41	9.08	1355.0	1507.61	6761.3	25.2	9.6	1.3	3.9	2.7	0.6
42	8.00	1495.4	545.46	5737.2	19.5	7.1	2.0	6.7	3.5	1.0
43	3.02	6724.9	0.00	2893.5	9.8	0.0	2.2	1.7	0.0	0.4
44	2.10	7692.3	0.00	3776.4	10.5	0.0	2.2	1.5	0.0	0.5
45	0.67	12391.6	0.00	0.0	3.3	0.0	0.0	0.7	0.0	0.0
46	0.86	18975.3	0.00	0.0	5.5	0.0	0.0	1.0	0.0	0.0
47	1.07	12610.3	0.00	0.0	4.7	0.0	2.2	1.0	0.0	0.7
48	0.50	7892.7	0.00	0.0	3.0	0.0	0.6	0.7	0.0	0.4

XCAN = Mean canopy height (m).
PD1 to PD3 = Total density of the canopy, subcanopy and shrubs in trees (ha).
DBH1 to DBH3 = Mean diameter at breast height (cm) of the canopy, subcanopy and shrubs.
WID1 to WID3 = Mean width of the crown (m) of the canopy, subcanopy and shrubs.

APPENDIX 4

BASIC program for calculation of density indices

```
100 !This program calculates an effective radius of detection from
110 !from the ratio of near to total birds using the model
120 !   P = (1 - 0.3849/A)/A^2  (Dawson pers. comm. 1982)
130 !Where A is the effective radius of detection divided by 20M.
140 !This equation is derived from a simple linear model of detect
ion,
150 !modified for point counts (Jarvinen and Vaisanen 1975).
160 DEFINE FILE #1 = 'OUTPUT'
170 PRINT "NUMBER OF DENSITIES TO BE CALCULATED"
180 INPUT I
190 FOR X = 1 TO I
200 PRINT "NUMBER OF STATION COUNTS"
210 INPUT Q
220 PRINT "NUMBER OF BIRDS OBSERVED NEAR"
230 INPUT N
240 PRINT "NUMBER OF BIRDS OBSERVED FAR"
250 INPUT F
260 T=N+F
270 L=N/T
280 GOSUB 330
290 WRITE #1,"  "
300 NEXT X
310 CLOSE #1
320 END
330 !
340 ! Subroutine to calculate effective radius and density
350 !
360 IF L>0 THEN 390
370 WRITE #1, " -1  ":" -1  ":
380 GOTO 510
390 IF L<1 THEN 420
400 WRITE #1, " -1  ":" -1  ":
410 GOTO 510
420 A = 1
430 E=L-(1-0.3849/A)/A^2
440 IF ABS(E)<1.0000E-03 THEN 470
450 A=A-E
460 GOTO 430
470 LET V=20*A
480 WRITE #1 USING '###.#',V:
490 LET W=T/3.14159/((20*A)^2)*10000/Q
500 WRITE #1 USING '##.##',W:
510 RETURN
520 END
```

APPENDIX 5

Total numbers of birds observed at each station (80 counts)

STATION	WARBLER	WHITEHEAD	FANTAIL	SILVEREYE	CHAFFINCH	RIFLEMAN	TOMTIT	BELLBIRD	TUI	PIGEON	BLACKBIRD	DUNNOCK	SHINING CUCKOO	PIPIT	LONG TAILED CUCKOO	FALCON	MAGPIE	PARAKEET	THRUSH	KINGFISHER	OTHER	UFO
1	59	33	81	175	36	20	29	6	1	0	5	0	1	0	0	0	5	0	1	3	0	1
2	97	62	73	135	25	19	44	10	0	0	19	0	2	0	0	0	0	0	1	3	1	3
3	42	34	67	72	16	21	36	5	0	0	12	1	2	0	1	0	1	0	0	1	2	2
4	66	33	69	131	17	11	57	9	3	0	13	1	0	0	0	0	0	0	0	1	3	0
5	79	28	61	96	14	29	57	11	1	0	13	0	2	0	1	0	1	0	1	2	0	0
6	77	17	48	54	8	30	28	13	4	0	10	0	1	0	0	0	1	0	1	5	1	1
7	63	23	52	59	7	16	39	7	1	0	5	0	0	0	0	1	0	0	1	3	0	0
8	67	33	42	44	9	15	36	8	0	0	7	0	4	0	2	0	0	0	1	3	0	1
9	79	135	8	79	13	69	58	8	8	3	10	0	1	0	3	0	0	3	1	0	0	0
10	82	155	16	61	16	50	60	14	6	16	14	0	1	0	2	0	0	14	0	0	0	0
11	91	170	13	83	22	31	65	32	11	13	15	0	3	0	3	2	1	6	0	0	0	0
12	75	102	16	55	15	50	40	15	5	15	10	0	1	0	1	0	0	2	0	0	0	0
13	75	96	18	56	9	47	42	23	6	9	15	0	1	0	1	0	0	0	2	0	0	1
14	83	116	16	59	12	42	55	21	4	10	19	0	2	0	0	3	0	6	0	0	0	1
15	85	143	16	104	18	37	50	25	11	8	14	0	0	0	2	1	1	3	2	0	0	1
16	104	121	19	99	26	37	75	29	7	5	20	1	3	0	1	1	1	6	1	0	1	0
17	41	41	44	59	8	22	26	5	0	0	2	0	0	0	2	0	0	0	0	0	0	0
18	91	113	54	133	18	41	76	34	2	3	7	0	5	0	4	0	0	1	2	3	0	2
19	98	160	44	102	18	66	70	38	8	9	10	0	7	0	1	4	0	2	1	1	0	0
20	82	161	14	66	18	38	61	30	4	11	13	0	4	0	1	0	1	2	2	0	0	1
21	79	125	21	37	16	21	53	10	4	5	10	0	3	0	1	0	0	3	0	0	0	1
22	45	97	4	30	8	31	62	10	5	1	13	0	0	0	1	2	0	3	0	0	1	0
23	54	97	1	27	6	37	56	6	0	1	5	0	0	0	0	0	0	2	0	0	0	1
24	40	93	1	27	7	17	42	3	0	0	5	0	0	0	0	0	0	3	0	0	0	0
25	66	51	0	38	5	39	28	10	1	0	10	1	0	0	1	0	1	0	0	0	1	0
26	59	102	1	54	10	28	55	10	3	0	10	0	1	0	2	0	0	2	0	0	0	0
27	49	87	1	40	8	47	41	6	0	0	16	1	1	0	1	0	1	3	1	0	2	1
28	28	54	1	41	4	19	43	12	0	0	12	0	0	0	3	1	0	1	0	0	0	2
29	51	65	0	34	5	8	54	13	5	2	19	2	0	0	0	2	0	4	0	0	0	0
30	54	72	1	23	12	39	56	9	0	1	11	0	1	0	1	0	0	3	0	0	0	0
31	53	65	2	24	12	22	46	19	2	0	18	0	0	0	1	0	1	2	0	0	2	0
32	76	147	5	44	15	22	49	29	6	4	37	1	7	0	3	1	1	1	0	0	3	0
33	71	36	9	50	24	46	36	30	1	0	22	1	1	0	2	0	0	0	4	0	0	1
34	66	26	3	33	16	36	40	19	1	0	12	2	0	0	1	0	0	1	1	0	0	0
35	58	25	4	14	9	27	38	26	3	0	13	1	0	0	2	0	0	1	1	0	0	0
36	54	29	5	34	13	39	45	24	1	0	18	0	1	0	1	0	3	0	0	0	0	0
37	71	44	8	46	13	50	67	22	3	1	18	0	0	0	0	1	4	0	1	0	0	1
38	51	56	3	26	11	50	44	8	2	0	12	0	0	0	0	0	1	0	0	0	0	0
39	63	83	8	33	9	44	37	16	4	1	12	0	1	0	1	0	4	1	0	0	0	1
40	93	83	2	52	10	49	43	18	3	1	20	0	1	0	0	0	4	0	1	1	0	1
41	60	80	4	54	21	15	61	27	8	1	28	1	2	0	1	0	3	1	0	0	0	0
42	41	22	1	58	11	4	54	16	2	1	27	9	0	0	0	0	0	0	1	0	0	0
43	45	52	0	62	12	2	40	23	6	0	28	11	1	2	1	1	0	1	0	0	0	0
44	31	8	0	44	11	0	17	13	1	0	22	18	0	0	0	2	1	1	0	0	2	0
45	25	0	0	44	9	0	15	13	1	0	28	27	0	5	1	1	0	0	0	0	0	0
46	32	2	0	60	14	0	23	16	6	0	40	29	0	6	0	2	0	0	0	0	0	1
47	25	2	0	68	15	0	19	20	5	0	29	46	1	4	0	5	2	0	0	0	0	0
48	18	1	0	34	15	0	11	4	3	1	27	37	2	3	0	2	0	0	0	0	0	0

APPENDIX 6

Mean bird density at each station (birds per hectare)

STATION	WARBLER	WHITEHEAD	FANTAIL	SILVEREYE	CHAFFINCH	RIFLEMAN	TOMTIT	BELLBIRD	TUI	PIGEON	BLACKBIRD	DUNNOCK	PIPIT
1	1.801	1.110	3.465	5.620	0.366	3.355	0.545	0.031	0.020	0.000	0.127	0.000	0.000
2	2.962	2.085	3.122	4.335	0.254	3.188	0.827	0.051	0.000	0.000	0.482	0.000	0.000
3	1.282	1.143	2.866	2.312	0.162	3.523	0.677	0.026	0.000	0.000	0.304	0.004	0.000
4	2.015	1.110	2.951	4.207	0.173	1.845	1.072	0.046	0.061	0.000	0.330	0.004	0.000
5	2.412	0.941	2.609	3.083	0.142	4.865	1.072	0.057	0.020	0.000	0.330	0.000	0.000
6	2.351	0.572	2.053	1.734	0.081	5.033	0.527	0.067	0.081	0.000	0.254	0.000	0.000
7	1.923	0.773	2.224	1.895	0.071	2.684	0.733	0.036	0.020	0.000	0.127	0.000	0.000
8	2.046	1.110	1.796	1.413	0.091	2.517	0.677	0.041	0.000	0.000	0.178	0.000	0.000
9	1.223	2.800	0.296	1.411	0.034	11.427	1.237	0.034	0.092	0.433	0.072	0.000	0.000
10	1.269	3.215	0.592	1.089	0.042	8.281	1.279	0.059	0.069	2.310	0.101	0.000	0.000
11	1.409	3.526	0.481	1.482	0.058	5.134	1.386	0.136	0.127	1.877	0.109	0.000	0.000
12	1.161	2.115	0.592	0.982	0.040	8.281	0.853	0.064	0.058	2.166	0.072	0.000	0.000
13	1.161	1.991	0.666	1.000	0.024	7.784	0.895	0.098	0.069	1.300	0.109	0.000	0.000
14	1.285	2.406	0.592	1.054	0.032	6.956	1.173	0.089	0.046	1.444	0.138	0.000	0.000
15	1.316	2.966	0.592	1.857	0.048	6.128	1.066	0.106	0.127	1.155	0.101	0.000	0.000
16	1.610	2.510	0.703	1.768	0.069	6.128	1.599	0.123	0.081	0.722	0.145	0.004	0.000
17	1.252	1.379	1.882	1.895	0.081	3.691	0.489	0.026	0.000	0.000	0.051	0.000	0.000
18	2.778	3.799	2.310	4.271	0.183	6.879	1.429	0.175	0.040	0.298	0.178	0.000	0.000
19	1.517	3.318	1.627	1.822	0.048	10.931	1.492	0.161	0.092	1.300	0.072	0.000	0.000
20	1.269	3.339	0.518	1.179	0.048	6.293	1.301	0.127	0.046	1.588	0.094	0.000	0.000
21	1.262	1.861	0.617	0.650	0.130	3.569	0.979	0.109	0.052	0.680	0.045	0.000	0.000
22	0.719	1.444	0.118	0.527	0.065	5.269	1.146	0.109	0.065	0.136	0.059	0.000	0.000
23	0.863	1.444	0.029	0.474	0.049	6.289	1.035	0.065	0.000	0.136	0.023	0.000	0.000
24	0.639	1.384	0.029	0.474	0.057	2.890	0.776	0.033	0.000	0.000	0.023	0.000	0.000
25	1.055	0.759	0.000	0.667	0.040	6.629	0.517	0.109	0.013	0.000	0.045	0.008	0.000
26	0.943	1.518	0.029	0.948	0.081	4.759	1.016	0.109	0.039	0.000	0.045	0.000	0.000
27	0.783	1.295	0.029	0.702	0.065	7.989	0.758	0.065	0.000	0.000	0.072	0.008	0.000
28	0.447	0.804	0.029	0.720	0.032	3.229	0.795	0.130	0.000	0.000	0.054	0.000	0.000
29	0.815	0.968	0.000	0.597	0.040	1.360	0.998	0.141	0.065	0.272	0.086	0.015	0.000
30	0.863	1.072	0.029	0.404	0.097	6.629	1.035	0.098	0.000	0.136	0.050	0.000	0.000
31	0.847	0.968	0.059	0.421	0.097	3.739	0.850	0.207	0.026	0.000	0.081	0.000	0.000
32	1.214	2.188	0.147	0.773	0.121	3.739	0.906	0.315	0.078	0.544	0.167	0.008	0.000
33	1.542	0.484	0.368	0.518	0.154	8.244	0.665	0.061	0.006	0.000	0.039	0.004	0.000
34	1.434	0.350	0.123	0.342	0.103	6.452	0.739	0.039	0.006	0.000	0.021	0.008	0.000
35	1.260	0.336	0.163	0.145	0.058	4.839	0.702	0.053	0.019	0.000	0.023	0.004	0.000
36	1.173	0.390	0.204	0.352	0.083	6.990	0.832	0.049	0.006	0.000	0.032	0.000	0.000
37	1.542	0.592	0.327	0.476	0.083	8.961	1.238	0.045	0.019	0.099	0.032	0.000	0.000
38	1.108	0.753	0.123	0.269	0.070	8.961	0.813	0.016	0.012	0.000	0.021	0.000	0.000
39	1.368	1.116	0.327	0.342	0.058	7.886	0.684	0.033	0.025	0.099	0.021	0.000	0.000
40	2.020	1.116	0.082	0.538	0.064	8.782	0.795	0.037	0.019	0.099	0.035	0.000	0.000
41	0.959	1.191	0.118	0.948	0.170	2.550	1.127	0.294	0.104	0.136	0.127	0.008	0.000
42	0.655	0.327	0.029	1.019	0.089	0.680	0.998	0.174	0.026	0.136	0.122	0.068	0.000
43	0.113	0.207	0.000	0.963	0.035	0.008	0.288	0.029	0.024	0.000	0.089	0.121	0.049
44	0.078	0.032	0.000	0.684	0.032	0.000	0.123	0.017	0.004	0.000	0.070	0.198	0.000
45	0.063	0.000	0.000	0.684	0.026	0.000	0.108	0.017	0.004	0.000	0.089	0.296	0.124
46	0.080	0.008	0.000	0.932	0.041	0.000	0.166	0.020	0.024	0.000	0.127	0.318	0.148
47	0.063	0.008	0.000	1.057	0.044	0.000	0.137	0.025	0.020	0.000	0.092	0.505	0.099
48	0.045	0.004	0.000	0.528	0.044	0.000	0.079	0.005	0.012	0.099	0.086	0.406	0.074

APPENDIX 7

Pearsons correlation coefficients of bird species densities with variables of the vegetation

Structural parameters of the vegetation

Plant Codes	Bird Species Codes (Scientific names in table 2.2)										
	WARB	WHIT	FANT	SILV	CHAF	RIFL	TOMT	BELL	TUI	PIGE	BLAC
XCAN	.620**	.360	.677**	.565**	.298	.092	.093	-.239	.157	.319	.423*
PD1	-.460*	-.208	-.372	-.284	-.198	-.470*	-.085	.349	.075	-.139	-.139
PD2	.199	.246	.119	.055	.205	-.069	.161	.130	.305	.274	.191
PD3	-.465*	-.235	-.482*	-.454*	-.156	-.020	-.155	.281	-.167	-.222	-.372
DBH1	.381	.409*	.324	.246	.008	.251	.310	-.176	.045	.347	.112
DBH2	.030	.082	.184	.050	-.193	.106	-.054	-.265	-.060	.200	.057
DBH3	.498**	.008	.427*	.311	.188	.012	.111	-.266	.054	.056	.423*
WID1	.507**	.252	.445*	.326	.087	.080	.188	-.139	.050	.223	.278
WID2	.168	.200	.368	.264	-.023	-.213	.139	.113	.216	.244	.348
WID3	.480*	-.026	.495**	.384	.239	-.143	.043	-.184	.158	.091	.426*

Point height intercepts

Plant Codes	Bird Species Codes (Scientific names in table 2.1)										
	WARB	WHIT	FANT	SILV	CHAF	RIFL	TOMT	BELL	TUI	PIGE	BLAC
RIMU	-.243	.017	-.293	-.245	-.295	.253	-.033	.093	.062	.053	-.285
MIRO	-.038	.504**	-.105	-.005	-.294	.446*	.329	.226	.285	.452*	-.149
HALL	-.377	-.259	-.373	-.252	-.073	-.198	-.137	.471*	-.005	-.209	-.166
PHYL	-.466*	-.058	-.378	-.295	-.267	-.124	-.028	.104	-.060	-.066	-.239
RBEE	.663**	.059	.786**	.683**	.506**	-.319	-.175	-.240	-.234	-.203	.566**
RATA	.288	-.021	.186	.156	.180	.113	.021	-.166	-.043	-.028	.162
KAMA	-.310	-.035	-.579**	-.499**	-.395*	.233	.074	.066	.047	.021	-.437*
MAHO	.115	.030	.286	.213	.127	-.024	-.033	-.135	.001	.077	.339
TORO	-.329	-.156	-.435*	-.457*	-.120	.005	-.056	.329	.001	.034	-.287
BRDL	-.350	-.257	-.154	-.151	-.122	-.144	-.218	.084	-.231	-.064	-.118
HINA	.209	-.057	.198	.100	.097	-.045	-.129	-.084	-.106	-.165	.117
PUTA	.245	-.173	.273	.172	.175	-.137	-.088	-.274	-.045	-.022	.191
AXIL	.344	.067	.223	.101	-.047	.158	-.031	-.154	.110	.031	.090
COLO	-.260	-.300	-.255	-.176	.156	-.276	-.044	.511*	.058	-.187	-.066
CFOE	-.189	-.061	-.158	-.167	.074	-.323	.025	.419*	.133	.030	-.086
CPOL	-.276	-.198	-.247	-.218	-.037	-.160	-.121	.373	-.110	-.167	-.111
TFER	.380	-.175	.527**	.327	.229	-.197	-.138	-.303	-.063	-.149	.480*

* Two tailed test of significance P < 0.01, with 40 degrees of freedom.
** Two tailed test of significance P < 0.001, with 40 degrees of freedom.

Plant species scientific names in table 1.1.
Full names for each structural variable in appendix 3.

Stations 43 through 48 were excluded from the analyses.

Appendix 7 continued

All tiers

Plant Codes	Bird Species Codes (Scientific names in table 2.2)										
	WARB	WHIT	FANT	SILV	CHAF	RIFL	TOMT	BELL	TUI	PIGE	BLAC
RIMU	-.237	.481*	-.280	-.245	-.465*	.446*	.314	-.026	.361	.737**	-.306
MIRO	.006	.774**	-.119	-.053	-.396*	.431*	.522**	.158	.519**	.731**	-.168
HALL	-.697**	-.105	-.644**	-.488*	-.362	-.036	-.014	.278	-.067	-.151	-.431*
PHYL	-.580**	.079	-.483*	-.371	-.383	.021	.055	.087	.013	.081	-.358
RBEE	.628**	-.026	.807**	.744**	.646**	-.368	-.255	-.286	-.219	-.241	.605**
RATA	.321	-.020	.296	.195	.032	-.004	.035	-.244	-.016	.092	.322
KAMA	.167	-.024	.013	.066	.117	.339	-.097	-.071	.027	-.143	-.159
MAHO	.414*	-.108	.576**	.476*	.449*	-.171	-.060	-.297	-.188	-.156	.495**
TORO	-.322	.038	-.616**	-.595**	-.287	.394*	.175	.294	.183	.238	-.479*
BRDL	.057	-.182	.122	.011	-.104	-.101	.001	.017	-.054	-.082	.172
HINA	.483*	.664**	.323	.364	-.031	.320	.513**	.125	.315	.433*	.217
PUTA	.497**	-.033	.540**	.447*	.259	-.185	-.085	-.222	.020	-.028	.397*
AXIL	.487*	.272	.462*	.345	.114	.133	.111	-.184	.184	.197	.360
COLO	-.273	-.465*	-.368	-.345	.052	-.149	-.084	.325	-.144	-.243	-.227
CFOE	-.520**	-.033	-.466*	-.331	-.187	-.068	.197	.374	.230	-.104	-.281
CPOL	-.640**	-.214	-.654**	-.584**	-.391	.123	-.094	.053	-.254	-.123	-.569**
TFER	.383	-.040	.464*	.284	.102	-.094	-.007	-.300	.007	.042	.459*

Canopy

Plant Codes	Bird Species Codes (Scientific names in table 2.1)										
	WARB	WHIT	FANT	SILV	CHAF	RIFL	TOMT	BELL	TUI	PIGE	BLAC
RIMU	-.205	.422*	-.217	-.183	-.376	.401*	.279	-.024	.279	.658**	-.241
MIRO	.033	.728**	-.047	.072	-.249	.421*	.533**	.232	.450*	.614**	-.090
HALL	-.552**	-.167	-.445*	-.312	-.140	-.262	-.030	.432*	-.040	-.211	-.193
PHYL	-.519**	-.177	-.413*	-.317	-.261	-.222	-.101	.169	-.148	-.230	-.267
RBEE	.643**	-.005	.818**	.721**	.603**	-.374	-.265	-.310	-.227	-.214	.613**
KAMA	-.453*	-.295	-.728**	-.698**	-.408*	.332	.012	.163	-.067	-.176	-.557**
TORO	-.249	-.084	-.386	-.366	-.089	.183	.085	.159	.146	.044	-.316
BRDL	-.185	-.303	-.216	-.234	-.209	.000	-.052	.055	-.112	-.077	-.157
PUTA	.167	-.059	.273	.129	-.013	-.074	-.021	-.221	.015	.122	.266
TFER	.312	-.063	.504**	.411*	.164	-.234	-.103	-.202	.146	.050	.429*

* Two tailed test of significance P < 0.01, with 40 degrees of freedom.
** Two tailed test of significance P < 0.001, with 40 degrees of freedom.

Plant species scientific names in table 1.1.
Full names for each structural variable in appendix 3.

Stations 43 through 48 were excluded from the analyses.

Appendix 7 continued

Subcanopy

Plant Codes	Bird Species Codes (Scientific names in table 2.1)										
	WARB	WHIT	FANT	SILV	CHAF	RIFL	TOMT	BELL	TUI	PIGE	BLAC
MIRO	-.213	.422*	-.184	-.125	-.406*	.375	.369	.001	.270	.437*	-.220
HALL	-.503**	-.174	-.492**	-.392	-.228	.062	-.116	.212	-.144	-.216	-.319
PHYL	-.321	.242	-.261	-.227	-.187	-.038	.161	.037	-.011	.223	-.208
RBEE	.811**	-.008	.801**	.707**	.481*	-.302	-.112	-.209	-.102	-.247	.767**
KAMA	.353	.350	.436*	.487*	.281	.157	.054	-.169	-.014	.093	.182
MAHO	.322	-.035	.537**	.473*	.399*	-.152	.017	-.248	-.090	-.057	.443*
TORO	-.295	-.006	-.593**	-.593**	-.238	.338	.110	.298	.154	.213	-.480*
PUTA	.673**	-.017	.650**	.584**	.390	-.250	-.003	-.186	.124	-.074	.667**
AXIL	.420*	.192	.193	.091	-.096	.202	.078	-.189	.220	.190	.094
COLO	-.187	-.451*	-.293	-.289	.109	-.099	-.082	.236	-.132	-.246	-.198
TFER	.265	.007	.508**	.286	.078	-.199	-.059	-.227	.001	.040	.513**

Shrubs

Plant Codes	Bird Species Codes (Scientific names in table 2.1)										
	WARB	WHIT	FANT	SILV	CHAF	RIFL	TOMT	BELL	TUI	PIGE	BLAC
RIMU	-.142	.241	-.228	-.243	-.397*	.223	.136	.017	.307	.350	-.256
MIRO	.108	.515**	.028	-.044	-.342	.102	.270	-.006	.372	.494**	-.029
HALL	-.614**	-.010	-.587**	-.454*	-.439*	.074	.048	.073	-.028	-.015	-.469*
PHYL	-.270	.275	-.247	-.175	-.277	.288	.190	-.045	.200	.339	-.210
RBEE	.484*	.010	.467*	.391	.286	-.215	.044	-.054	.140	-.057	.501**
KAMA	.380	-.061	.603**	.637**	.608**	-.228	-.298	-.174	.046	-.126	.281
TORO	-.073	.357	-.140	-.105	-.113	.072	.261	.390	.322	.410*	.043
HINA	.389	.512**	.354	.318	-.018	.272	.385	.159	.222	.323	.161
PUTA	.514**	-.002	.537**	.494**	.353	-.214	-.164	-.171	-.069	-.143	.262
AXIL	.461*	.305	.464*	.358	.115	.132	.161	-.151	.185	.210	.388
COLO	-.312	-.468*	-.359	-.316	.058	-.252	-.108	.368	-.146	-.266	-.192
CFOE	-.466*	-.077	-.375	-.301	-.144	-.139	.091	.404*	.132	-.106	-.230
CPOL	-.596**	-.192	-.638**	-.586**	-.387	.194	-.084	.047	-.257	-.127	-.561**
TFER	.405*	-.054	.337	.197	.087	.027	.063	-.311	-.025	.035	.349

* Two tailed test of significance $P < 0.01$, with 40 degrees of freedom.
** Two tailed test of significance $P < 0.001$, with 40 degrees of freedom.

Plant species scientific names in table 1.1
Full names for each structural variable in appendix 3.

Stations 43 through 48 were excluded from the analyses.

APPENDIX 8

Mean monthly five-minute bird counts

Month (from November 1982 = 1)

Month	WARB	WHIT	FANT	SILV	CHAF	RIFL	TOMT	BELL	TUI	PIGE	BLAC
1	0.74	0.71	0.15	0.19	0.30	0.25	0.45	0.01	0.01	0.04	0.41
2	0.84	0.93	0.26	0.41	0.48	0.38	0.77	0.03	0.03	0.00	0.53
3	0.46	0.73	0.13	0.14	0.25	0.33	0.63	0.19	0.00	0.01	0.17
4	0.65	1.29	0.26	1.14	0.08	0.65	0.39	0.03	0.04	0.04	0.02
5	1.03	0.73	0.24	0.99	0.05	0.52	0.47	0.02	0.09	0.04	0.04
6	0.44	0.25	0.28	0.86	0.01	0.35	0.53	0.24	0.07	0.00	0.07
7	0.19	0.43	0.18	1.61	0.03	0.30	0.40	0.23	0.03	0.02	0.06
8	0.22	0.48	0.21	1.19	0.02	0.46	0.44	0.11	0.05	0.06	0.02
9	0.60	0.81	0.13	1.02	0.03	0.38	0.48	0.03	0.03	0.05	0.04
10	0.92	1.16	0.19	0.38	0.02	0.41	0.57	0.27	0.02	0.06	0.05
11	0.91	0.80	0.22	0.17	0.08	0.28	0.54	0.15	0.05	0.02	0.14
12	0.90	1.17	0.13	0.53	0.26	0.21	0.56	0.20	0.01	0.03	0.28
13	1.06	0.98	0.21	0.27	0.39	0.22	0.92	0.12	0.02	0.02	0.64
14	0.88	0.96	0.17	0.10	0.49	0.43	0.74	0.17	0.06	0.00	0.64
15	0.60	1.53	0.22	0.17	0.26	0.42	0.63	0.28	0.02	0.01	0.22
16	0.77	1.29	0.25	0.89	0.07	0.51	0.27	0.15	0.04	0.04	0.04
17	1.06	0.82	0.39	0.87	0.06	0.39	0.63	0.29	0.07	0.08	0.08
18	1.15	0.65	0.31	1.72	0.13	0.35	0.67	0.65	0.06	0.08	0.06
19	0.74	0.49	0.24	1.26	0.16	0.24	0.40	0.47	0.03	0.05	0.06
20	0.81	0.52	0.19	1.04	0.10	0.27	0.35	0.38	0.07	0.05	0.02
21	0.84	0.68	0.13	1.71	0.09	0.33	0.56	0.16	0.11	0.06	0.04
22	0.85	0.84	0.16	0.73	0.07	0.31	0.63	0.12	0.04	0.04	0.04
23	0.92	1.01	0.38	0.70	0.04	0.22	0.60	0.26	0.05	0.02	0.06
24	1.21	1.07	0.16	0.69	0.10	0.21	0.56	0.13	0.01	0.02	0.34
25	1.10	1.39	0.23	0.34	0.52	0.26	1.05	0.13	0.01	0.01	0.73
26	0.82	0.98	0.19	0.26	0.37	0.31	0.75	0.16	0.04	0.00	0.53
27	0.55	0.94	0.39	0.76	0.19	0.63	0.44	0.13	0.04	0.03	0.18
28	0.59	0.90	0.24	1.02	0.14	0.56	0.42	0.26	0.08	0.01	0.07

Month	DUNN	SHIN	PIPI	LTCU	FALC	MAGP	PARA	THRU	Other	UFO
1	0.06	0.01	0.00	0.09	0.00	0.01	0.00	0.00	0.00	0.00
2	0.06	0.06	0.06	0.04	0.01	0.00	0.00	0.01	0.00	0.00
3	0.08	0.06	0.02	0.08	0.03	0.01	0.00	0.01	0.00	0.00
4	0.02	0.01	0.02	0.04	0.07	0.05	0.00	0.00	0.00	0.01
5	0.00	0.00	0.02	0.00	0.03	0.02	0.00	0.00	0.00	0.00
6	0.01	0.01	0.01	0.00	0.01	0.03	0.00	0.00	0.00	0.01
7	0.01	0.00	0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.01
8	0.03	0.00	0.01	0.00	0.04	0.01	0.02	0.00	0.00	0.04
9	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00
10	0.02	0.00	0.00	0.00	0.02	0.00	0.01	0.00	0.00	0.01
11	0.01	0.00	0.00	0.00	0.00	0.04	0.00	0.01	0.01	0.00
12	0.09	0.02	0.01	0.00	0.02	0.01	0.00	0.00	0.00	0.01
13	0.09	0.03	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.00
14	0.08	0.03	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.01
15	0.06	0.03	0.00	0.03	0.02	0.01	0.04	0.01	0.00	0.00
16	0.03	0.01	0.00	0.02	0.03	0.01	0.04	0.01	0.00	0.01
17	0.02	0.00	0.00	0.00	0.05	0.00	0.03	0.00	0.00	0.03
18	0.03	0.00	0.00	0.00	0.03	0.00	0.01	0.01	0.00	0.00
19	0.00	0.00	0.00	0.00	0.04	0.00	0.02	0.00	0.00	0.01
20	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.01
21	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.00	0.01
22	0.02	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.00	0.00
23	0.05	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.00
24	0.13	0.03	0.01	0.00	0.01	0.01	0.00	0.01	0.01	0.01
25	0.13	0.11	0.00	0.02	0.02	0.01	0.01	0.00	0.04	0.04
26	0.08	0.03	0.00	0.02	0.02	0.01	0.00	0.02	0.08	0.02
27	0.04	0.00	0.00	0.04	0.01	0.01	0.00	0.03	0.01	0.02
28	0.19	0.00	0.00	0.01	0.04	0.04	0.00	0.00	0.01	0.01

Bird species scientific names in table 2.2.

APPENDIX 9

Percent of each class of behaviour observed

Bird code (scientific names in table 2.2)

Behaviour	WARB	WHIT	FANT	SILV	CHAF	RIFL	TOMT	BELL	TUI	PIGE	BLAC
Feed	87.5	81.4	13.5	86.1	37.8	83.1	13.1	57.0	46.1	26.8	82.4
Perch	3.5	1.0	55.4	4.5	24.4	1.5	59.1	15.6	17.5	70.9	14.9
Sing	7.3	15.9	26.3	7.6	34.4	13.6	23.6	25.0	27.3	.3	1.4
Preen	.6	1.0	2.3	1.4	1.1	.9	2.8	.8	9.1	1.9	1.4
Court	.5	.1	.2	.0	.0	.1	.5	.0	.0	.0	.0
Fly	.2	.0	1.2	.3	.0	.0	.1	.8	.0	.1	.0
Aggress	.5	.5	1.1	.0	2.2	.7	.9	.8	.0	.0	.0
TOTAL	1774	2278	1061	288	90	2064	1057	128	143	691	74

Canopy Station Observations

Behaviour	WARB	WHIT	FANT	SILV	CHAF	RIFL	TOMT	BELL	TUI	PIGE
Feed	83.0	54.8	22.0	80.2	3.0	68.5	3.2	22.7	39.1	17.4
Perch	2.6	.6	45.1	9.3	15.2	3.2	59.2	36.4	29.1	77.0
Sing	6.3	44.6	30.6	10.5	81.8	27.5	32.8	31.8	29.1	.0
Preen	7.3	.0	.0	.0	.0	.5	4.8	9.1	2.0	5.7
Court	.3	.0	.6	.0	.0	.5	.0	.0	.0	.0
Aggress	.5	.0	1.7	.0	.0	.0	.0	.0	.7	.0
TOTAL	383	531	346	86	33	222	125	22	151	230

APPENDIX 10

Percent foraging use of substrates

Ground observations

Bird code (scientific names in table 2.2)

Substrate	WARB	WHIT	FANT	SILV	CHAF	RIFL	TOMT	BELL	TUI	PIGE	BLAC
Ground	.4	.0	1.4	.0	2.9	.2	37.7	.0	.0	.0	100
Twig	21.5	50.2	3.5	21.4	11.8	11.9	18.1	11.0	1.5	.0	.0
S. branch	4.4	22.3	3.5	10.5	17.6	18.4	6.5	39.7	10.6	.0	.0
L. branch	1.4	15.9	1.4	4.8	17.6	33.6	15.2	17.8	36.4	.0	.0
Limb	.1	1.5	.7	.0	.0	10.1	.0	.0	3.0	.0	.0
Trunk	.1	2.5	3.5	.4	5.9	24.3	18.1	4.1	.0	.0	.0
Foliage	72.2	7.6	7.7	57.7	44.1	1.5	4.3	23.3	1.5	.0	.0
Flower	.0	.0	.0	.4	.0	.0	.0	4.1	47.0	.0	.0
Fruit	.0	.0	.0	4.8	.0	.0	.0	.0	.0	100	.0
Air	.0	.0	78.3	.0	.0	.0	.0	.0	.0	.0	.0
TOTAL	1552	1854	143	248	34	1715	138	73	66	185	61

Canopy observations

Bird code (scientific names in table 2.2)

Substrate	WARB	WHIT	FANT	SILV	CHAF	RIFL	TOMT	BELL	TUI	PIGE
Ground	.0	.0	.0	.0	.0	.0	25.0	.0	.0	.0
Twig	27.7	49.5	.0	15.9	.0	4.6	.0	20.0	.0	.0
S. branch	12.9	30.9	.0	4.3	100	19.7	.0	40.0	6.8	.0
L. branch	.9	7.2	.0	.0	.0	37.5	.0	.0	1.7	.0
Limb	.0	.3	.0	.0	.0	19.7	25.0	.0	.0	.0
Trunk	.0	.0	.0	.0	.0	18.4	.0	.0	.0	.0
Foliage	58.2	12.0	.0	20.3	.0	.0	50.0	40.0	.0	.0
Flower	.0	.0	.0	53.6	.0	.0	.0	.0	91.5	.0
Fruit	.0	.0	.0	.0	.0	.0	.0	.0	.0	97.5
Air	.3	.0	100	5.8	.0	.0	.0	.0	.0	2.5
TOTAL	318	291	76	69	1	152	4	5	59	40

APPENDIX 11

Percent foraging use of tree species

Ground observations
Bird code (scientific names in table 2.2)

Tree code	WARB	WHIT	FANT	SILV	CHAF	RIFL	TOMT	BELL	TUI	PIGE	BLAC
Air	.0	.0	78.3	.0	.0	.0	.0	.0	.0	.0	.0
Ground	.5	.1	1.4	.0	2.9	.2	37.7	.0	.0	.0	100
RIMU	1.3	12.2	.7	2.8	.0	3.3	.0	1.4	10.6	.0	.0
MIRO	7.0	12.0	1.4	.4	23.5	4.8	2.9	.0	1.5	99.5	.0
HALL	1.2	.4	.0	.0	.0	1.3	1.4	.0	.0	.0	.0
PHYL	1.0	2.5	.0	1.2	.0	.5	2.9	1.4	.0	.0	.0
RBEE	16.6	19.6	7.0	61.7	20.6	8.0	7.2	43.8	.0	.0	.0
RATA	.3	.1	.0	.4	.0	.5	.0	4.1	47.0*	.0	.0
KAMA	44.1	42.3	8.4	10.1	32.4	63.5	32.6	46.6	39.4	.0	.0
MAHO	1.5	1.6	.0	1.6	8.8	2.7	.0	1.4	.0	.0	.0
TORO	16.4	7.2	.0	7.7	.0	9.7	8.0	1.4	1.5	.0	.0
BRDL	1.2	.4	.0	6.0	.0	1.1	.0	.0	.0	.0	.0
HINA	.3	.2	.0	.0	.0	.4	.0	.0	.0	.0	.0
PUTA	.8	.3	.0	.0	.0	.1	.0	.0	.0	.0	.0
AXIL	1.9	.2	.0	.4	.0	1.0	2.9	.0	.0	.0	.0
CFOE	.3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
CPOL	.2	.0	.0	2.0	.0	.0	.0	.0	.0	.0	.0
OLEC	.0	.0	.0	.4	11.8	.0	.0	.0	.0	.0	.0
TFER	2.0	.2	2.8	.0	.0	1.0	3.6	.0	.0	.0	.0
Others	3.7	.8	.0	5.2	.0	1.7	.7	.0	.0	.5	.0
TOTAL	1552	1854	143	248	34	1715	138	73	66	185	61

* = Northern rata (*Metrosideros robusta*)

Canopy observations

Tree code	WARB	WHIT	FANT	SILV	CHAF	RIFL	TOMT	BELL	TUI	PIGE
Air	.3	.0	100	5.8	.0	.0	.0	.0	.0	2.5
Air	.0	.0	.0	.0	.0	.0	25.0	.0	.0	.0
RIMU	30.8	70.4	.0	33.3	100	14.5	50.0	40.0	6.8	.0
MIRO	34.6	12.7	.0	.0	.0	28.3	25.0	.0	1.7	97.5
RBEE	5.3	4.5	.0	.0	.0	.0	.0	.0	.0	.0
NRAT *	.6	.7	.0	55.1	.0	.0	.0	.0	91.5	.0
KAMA	26.7	11.3	.0	4.3	.0	52.0	.0	60.0	.0	.0
TORO	.3	.3	.0	1.4	.0	.0	.0	.0	.0	.0
HINA	1.3	.0	.0	.0	.0	5.3	.0	.0	.0	.0
TOTAL	318	291	76	69	1	152	4	5	59	40

NRAT = Northern rata (*Metrosideros robusta*)
Tree species scientific names in table 1.1

APPENDIX 12

Percent foraging use of height classes

Ground observations

Bird code (scientific names in table 2.2)

Foraging height class (m)	WARB	WHIT	FANT	SILV	CHAF	RIFL	TOMT	BELL	TUI	PIGE	BLAC
.00	.5	.0	1.4	.0	2.9	.2	38.4	.0	.0	.0	100
2.00	9.7	1.2	8.4	8.9	11.8	3.4	16.7	2.7	.0	.0	.0
4.00	21.6	6.4	16.8	6.5	8.8	16.6	20.3	8.2	.0	.5	.0
6.00	22.0	14.7	18.9	11.7	8.8	27.2	15.2	6.8	.0	.0	.0
8.00	18.8	22.1	12.6	15.7	14.7	24.8	4.3	26.0	9.1	.0	.0
10.00	12.0	13.0	9.1	12.1	11.8	14.3	2.2	17.8	16.7	.0	.0
12.00	6.7	9.5	6.3	7.7	35.3	6.3	2.2	5.5	16.7	3.2	.0
14.00	4.1	8.7	7.0	11.3	.0	4.8	.0	2.7	1.5	17.8	.0
16.00	2.8	9.7	7.7	11.7	5.9	1.3	.7	.0	.0	37.8	.0
18.00	.8	8.1	4.2	6.9	.0	.6	.0	5.5	9.1	18.4	.0
20.00	.6	2.8	2.8	4.4	.0	.1	.0	17.8	.0	2.2	.0
22.00	.5	1.8	1.4	3.2	.0	.4	.0	6.8	.0	10.3	.0
24.00	.1	1.0	2.1	.0	.0	.0	.0	.0	.0	1.6	.0
26.00	.0	.6	1.4	.0	.0	.0	.0	.0	.0	3.8	.0
28.00	.0	.3	.0	.0	.0	.0	.0	.0	.0	4.3	.0
30.00	.0	.2	.0	.0	.0	.0	.0	.0	10.6	.0	.0
32.00+	.0	.0	.0	.0	.0	.0	.0	.0	36.4	.0	.0
TOTAL	1552	1854	143	248	34	1715	138	73	66	185	61

Canopy observations

	WARB	WHIT	FANT	SILV	CHAF	RIFL	TOMT	BELL	TUI	PIGE
.00	.0	.0	.0	.0	.0	.0	25.0	.0	.0	.0
2.00	.0	.3	.0	.0	.0	.0	.0	.0	.0	.0
4.00	.0	.3	.0	.0	.0	.0	.0	.0	.0	.0
6.00	.6	.0	.0	.0	.0	2.6	.0	.0	.0	.0
8.00	2.5	.7	.0	.0	.0	11.2	.0	.0	.0	.0
10.00	9.4	5.2	2.6	4.3	.0	20.4	.0	.0	.0	.0
12.00	23.3	6.5	3.9	1.4	.0	27.6	.0	.0	10.2	25.0
14.00	27.4	17.9	15.8	5.8	.0	30.3	25.0	60.0	3.4	60.0
16.00	23.3	29.6	19.7	11.6	.0	6.6	25.0	.0	8.5	12.5
18.00	3.1	14.4	14.5	10.1	100	1.3	.0	.0	.0	.0
20.00	7.2	14.1	9.2	5.8	.0	.0	25.0	40.0	.0	.0
22.00	1.6	5.8	14.5	5.8	.0	.0	.0	.0	.0	.0
24.00	.9	5.2	17.1	20.3	.0	.0	.0	.0	.0	.0
26.00	.0	.0	2.6	11.6	.0	.0	.0	.0	8.5	.0
28.00	.0	.0	.0	8.7	.0	.0	.0	.0	44.1	.0
30.00	.6	.0	.0	14.5	.0	.0	.0	.0	25.4	.0
32.00+	.0	.0	.0	.0	.0	.0	.0	.0	.0	2.5
TOTAL	318	291	76	69	1	152	4	5	59	40

APPENDIX 13

Seasonal foraging use of substrates (percent)
(Ground observations)

Summer

Bird code (scientific names in table 2.2)

Substrate	WARB	WHIT	FANT	SILV	CHAF	RIFL	TOMT	BELL	TUI	PIGE	BLAC
Ground	.3	.0	2.4	.0	.0	.1	19.2	.0	.0	.0	100
Twig	28.0	51.3	11.9	27.8	20.0	15.0	26.0	.0	.0	.0	.0
S. branch	3.3	20.0	9.5	5.6	40.0	18.5	11.0	.0	.0	.0	.0
L. branch	1.9	17.0	2.4	5.6	.0	35.2	19.2	.0	.0	.0	.0
Limb	.0	1.0	.0	.0	.0	8.7	.0	.0	.0	.0	.0
Trunk	.0	1.4	2.4	.0	10.0	21.2	20.5	.0	.0	.0	.0
Foliage	66.5	9.2	11.9	55.6	30.0	1.3	4.1	.0	.0	.0	.0
Flower	.0	.0	.0	5.6	.0	.0	.0	.0	100	.0	.0
Fruit	.0	.0	.0	.0	.0	.0	.0	.0	.0	100	.0
Air	.0	.0	59.5	.0	.0	.0	.0	.0	.0	.0	.0
Total	361	575	42	18	10	773	73	0	31	3	27

Autumn

Bird code (scientific names in table 2.2)

Substrate	WARB	WHIT	FANT	SILV	CHAF	RIFL	TOMT	BELL	TUI	PIGE	BLAC
Ground	.3	.0	2.1	.0	.0	.5	52.6	.0	.0	.0	100
Twig	19.2	47.4	.0	38.9	.0	8.4	10.5	14.3	.0	.0	.0
S. branch	2.8	21.3	.0	13.9	.0	17.5	2.6	52.4	.0	.0	.0
L. branch	1.7	15.6	2.1	.0	.0	37.6	10.5	4.8	.0	.0	.0
Limb	.0	1.8	2.1	.0	.0	9.4	.0	.0	.0	.0	.0
Trunk	.0	1.6	4.2	.0	.0	23.5	18.4	14.3	.0	.0	.0
Foliage	75.9	12.4	10.4	47.2	.0	3.1	5.3	.0	.0	.0	.0
Flower	.0	.0	.0	.0	.0	.0	.0	14.3	.0	.0	.0
Fruit	.0	.0	.0	.0	.0	.0	.0	.0	.0	100	.0
Air	.0	.0	79.2	.0	.0	.0	.0	.0	.0	.0	.0
Total	572	508	48	36	0	417	38	21	0	26	17

Appendix 13 continued

Winter

Bird code (scientific names in table 2.2)

Substrate	WARB	WHIT	FANT	SILV	CHAF	RIFL	TOMT	BELL	TUI	PIGE	BLAC
Ground	.8	.0	.0	.0	.0	.0	81.3	.0	.0	.0	100
Twig	17.0	52.5	.0	20.0	.0	7.9	.0	12.0	3.6	.0	.0
S. branch	4.3	22.6	4.2	7.1	.0	17.6	.0	28.0	10.7	.0	.0
L. branch	.5	16.6	.0	6.4	.0	34.5	18.8	32.0	78.6	.0	.0
Limb	.0	1.5	.0	.0	.0	15.2	.0	.0	7.1	.0	.0
Trunk	.3	3.3	.0	.7	.0	24.8	.0	.0	.0	.0	.0
Foliage	77.1	3.5	.0	61.4	.0	.0	.0	28.0	.0	.0	.0
Flower	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Fruit	.0	.0	.0	4.3	.0	.0	.0	.0	.0	100	.0
Air	.0	.0	95.8	.0	.0	.0	.0	.0	.0	.0	.0
Total	371	518	24	140	0	290	16	25	28	100	7

Spring

Bird code (scientific names in table 2.2)

Substrate	WARB	WHIT	FANT	SILV	CHAF	RIFL	TOMT	BELL	TUI	PIGE	BLAC
Ground	.0	.0	.0	.0	4.2	.4	45.5	.0	.0	.0	100
Twig	23.8	48.6	.0	11.1	8.3	13.1	18.2	7.4	.0	.0	.0
S. branch	10.1	29.2	.0	18.5	8.3	20.3	.0	40.7	57.1	.0	.0
L. branch	1.2	12.6	.0	3.7	25.0	19.9	.0	14.8	28.6	.0	.0
Limb	.4	1.6	.0	.0	.0	9.7	.0	.0	.0	.0	.0
Trunk	.0	5.5	6.9	.0	4.2	35.2	27.3	.0	.0	.0	.0
Foliage	64.5	2.4	3.4	55.6	50.0	1.3	9.1	37.0	14.3	.0	.0
Flower	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Fruit	.0	.0	.0	11.1	.0	.0	.0	.0	.0	100	.0
Air	.0	.0	89.7	.0	.0	.0	.0	.0	.0	.0	.0
Total	248	253	29	54	24	236	11	27	7	56	10

APPENDIX 14

Seasonal foraging use of tree species (percent)

(Ground observations only)

Summer

Bird code (scientific names in table 2.2)

	WARB	WHIT	FANT	SILV	CHAF	RIFL	TOMT	BELL	TUI	PIGE	BLAC
Tree code											
Air	.0	.0	59.5	.0	.0	.0	.0	.0	.0	.0	.0
Ground	.3	.0	2.4	.0	.0	.1	19.2	.0	.0	.0	100
RIMU	.3	14.1	2.4	22.2	.0	2.5	.0	.0	.0	.0	.0
MIRO	7.5	14.4	4.8	.0	.0	3.8	2.7	.0	.0	100	.0
HALL	1.1	.0	.0	.0	.0	1.2	1.4	.0	.0	.0	.0
PHYL	.8	.3	.0	.0	.0	.5	5.5	.0	.0	.0	.0
RBEE	11.6	13.9	16.7	44.4	20.0	6.7	11.0	.0	.0	.0	.0
RATA	.0	.3	.0	.0	.0	.8	.0	.0	100*	.0	.0
KAMA	47.4	40.9	11.9	22.2	50.0	62.5	42.5	.0	.0	.0	.0
MAHO	3.0	3.1	.0	11.1	30.0	4.4	.0	.0	.0	.0	.0
TORO	18.0	10.3	.0	.0	.0	12.4	8.2	.0	.0	.0	.0
BRDL	2.2	.9	.0	.0	.0	1.6	.0	.0	.0	.0	.0
HINA	.0	.2	.0	.0	.0	.3	.0	.0	.0	.0	.0
PUTA	2.8	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
AXIL	.8	.3	.0	.0	.0	1.2	4.1	.0	.0	.0	.0
CPOL	.3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
TFER	2.5	.2	.0	.0	.0	.8	4.1	.0	.0	.0	.0
Other	1.4	.9	.0	.0	.0	1.4	1.4	.0	.0	.0	.0
Total	361	575	42	18	10	773	73	0	31	3	27

Autumn

	WARB	WHIT	FANT	SILV	CHAF	RIFL	TOMT	BELL	TUI	PIGE	BLAC
Tree code											
Air	.0	.0	79.2	.0	.0	.0	.0	.0	.0	.0	.0
Ground	.3	.0	2.1	.0	.0	.5	52.6	.0	.0	.0	100
RIMU	.9	12.4	.0	8.3	.0	3.8	.0	4.8	.0	.0	.0
MIRO	7.3	15.7	.0	.0	.0	4.6	.0	.0	.0	100	.0
HALL	2.1	.6	.0	.0	.0	2.4	2.6	.0	.0	.0	.0
PHYL	.5	4.3	.0	2.8	.0	.5	.0	.0	.0	.0	.0
RBEE	10.5	22.2	.0	8.3	.0	10.8	2.6	9.5	.0	.0	.0
RATA	.5	.0	.0	.0	.0	.2	.0	14.3	.0	.0	.0
KAMA	45.3	34.1	12.5	11.1	.0	62.4	23.7	66.7	.0	.0	.0
MAHO	1.6	1.0	.0	5.6	.0	.5	.0	4.8	.0	.0	.0
TORO	21.2	7.1	.0	41.7	.0	8.9	13.2	.0	.0	.0	.0
BRDL	.7	.2	.0	5.6	.0	.2	.0	.0	.0	.0	.0
HINA	.3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
PUTA	.3	.2	.0	.0	.0	.2	.0	.0	.0	.0	.0
AXIL	2.8	.0	.0	.0	.0	.2	.0	.0	.0	.0	.0
CFOE	.3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
TFER	1.2	.4	8.3	.0	.0	2.4	5.3	.0	.0	.0	.0
Other	3.8	1.8	.0	16.7	.0	2.4	.0	.0	.0	.0	.0
Total	572	508	48	36	0	417	38	21	0	26	17

Tree species codes as in table 1.1   * = Metrosideros robusta

Appendix 14 continued

Winter
Bird code (scientific names in table 2.2)

Tree code	WARB	WHIT	FANT	SILV	CHAF	RIFL	TOMT	BELL	TUI	PIGE	BLAC
Air	.0	.0	95.8	.0	.0	.0	.0	.0	.0	.0	.0
Ground	.8	.0	.0	.0	.0	.0	81.3	.0	.0	.0	100
RIMU	2.7	11.8	.0	.0	.0	5.5	.0	.0	7.1	.0	.0
MIRO	7.5	6.2	.0	.0	.0	8.3	.0	.0	.0	100	.0
HALL	.3	.8	.0	.0	.0	.0	.0	.0	.0	.0	.0
PHYL	1.3	3.1	.0	1.4	.0	.3	.0	.0	.0	.0	.0
RBEE	28.3	21.0	4.2	74.3	.0	7.2	.0	32.0	.0	.0	.0
RATA	.3	.0	.0	.7	.0	.0	.0	.0	.0	.0	.0
KAMA	34.5	48.6	.0	10.0	.0	67.6	18.8	64.0	89.3	.0	.0
MAHO	.8	1.2	.0	.0	.0	2.1	.0	.0	.0	.0	.0
TORO	12.4	5.6	.0	2.9	.0	6.2	.0	4.0	3.6	.0	.0
BRDL	.3	.4	.0	5.7	.0	.3	.0	.0	.0	.0	.0
HINA	.0	.6	.0	.0	.0	.0	.0	.0	.0	.0	.0
PUTA	.0	.8	.0	.0	.0	.0	.0	.0	.0	.0	.0
AXIL	1.6	.0	.0	.7	.0	1.7	.0	.0	.0	.0	.0
CPOL	.0	.0	.0	3.6	.0	.0	.0	.0	.0	.0	.0
OLEC	.0	.0	.0	.7	.0	.0	.0	.0	.0	.0	.0
TFER	3.5	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Other	5.7	.0	.0	.0	.0	.7	.0	.0	.0	.0	.0
Total	371	518	24	140	0	290	16	25	28	100	7

Spring

Tree code	WARB	WHIT	FANT	SILV	CHAF	RIFL	TOMT	BELL	TUI	PIGE	BLAC
Air	.0	.0	89.7	.0	.0	.0	.0	.0	.0	.0	.0
Ground	.0	.0	.0	.0	4.2	.4	45.5	.0	.0	.0	100
RIMU	1.6	8.3	.0	.0	.0	2.5	.0	.0	71.4	.0	.0
MIRO	4.4	11.1	.0	1.9	33.3	4.2	18.2	.0	14.3	98.2	.0
HALL	.4	.0	.0	.0	.0	1.3	.0	.0	.0	.0	.0
PHYL	1.6	2.4	.0	.0	.0	.8	.0	3.7	.0	.0	.0
RBEE	20.6	24.5	6.9	70.4	20.8	8.5	9.1	81.5	.0	.0	.0
RATA	.4	.0	.0	.0	.0	.4	.0	.0	.0	.0	.0
KAMA	50.8	49.4	3.4	5.6	25.0	64.0	18.2	14.8	14.3	.0	.0
MAHO	.4	.0	.0	.0	.0	2.1	.0	.0	.0	.0	.0
TORO	8.9	4.0	.0	.0	.0	6.4	.0	.0	.0	.0	.0
BRDL	2.0	.0	.0	9.3	.0	2.1	.0	.0	.0	.0	.0
HINA	.8	.0	.0	.0	.0	2.1	.0	.0	.0	.0	.0
PUTA	.4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
AXIL	1.6	.4	.0	.0	.0	1.3	9.1	.0	.0	.0	.0
CFOE	.8	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
CPOL	.8	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
OLEC	.0	.0	.0	.0	16.7	.0	.0	.0	.0	.0	.0
TFER	.8	.0	.0	.0	.0	.8	.0	.0	.0	.0	.0
Other	3.6	.0	.0	13.0	.0	3.0	.0	.0	.0	1.8	.0
Total	248	253	29	54	24	236	11	27	7	56	10

APPENDIX 15

Seasonal foraging use of height classes (percent)
(Ground observations)

Summer

Bird code (scientific name in table 2.2)

Height (m)	WARB	WHIT	FANT	SILV	CHAF	RIFL	TOMT	BELL	TUI	PIGE	BLAC
2.00	4.7	2.4	7.1	.0	.0	2.8	16.4	.0	.0	.0	.0
4.00	21.9	6.8	16.7	.0	30.0	21.1	26.0	.0	.0	.0	.0
6.00	26.3	12.9	21.4	16.7	10.0	33.2	21.9	.0	.0	.0	.0
8.00	24.1	21.7	11.9	16.7	30.0	21.5	8.2	.0	.0	.0	.0
10.00	9.4	13.7	7.1	11.1	.0	12.5	4.1	.0	.0	.0	.0
12.00	6.4	11.8	7.1	11.1	20.0	4.7	2.7	.0	.0	100	.0
14.00	1.4	12.9	7.1	11.1	.0	3.0	.0	.0	.0	.0	.0
16.00	2.8	9.4	2.4	11.1	10.0	.6	1.4	.0	.0	.0	.0
18.00	1.9	3.0	4.8	11.1	.0	.0	.0	.0	.0	.0	.0
20.00	.8	1.6	4.8	11.1	.0	.0	.0	.0	.0	.0	.0
22.00	.0	2.3	2.4	.0	.0	.4	.0	.0	.0	.0	.0
24.00	.0	1.6	.0	.0	.0	.0	.0	.0	.0	.0	.0
26.00	.0	.0	4.8	.0	.0	.0	.0	.0	.0	.0	.0
28.00	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
30.00	.0	.0	.0	.0	.0	.0	.0	.0	22.6	.0	.0
32 +	.0	.0	.0	.0	.0	.0	.0	.0	77.4	.0	.0
Total	361	575	42	18	10	773	73	0	31	3	27

Autumn

Height (m)	WARB	WHIT	FANT	SILV	CHAF	RIFL	TOMT	BELL	TUI	PIGE	BLAC
2.00	12.6	.8	8.3	11.1	.0	5.0	15.8	4.8	.0	.0	.0
4.00	21.9	5.1	25.0	27.8	.0	17.7	15.8	.0	.0	.0	.0
6.00	20.6	13.6	29.2	30.6	.0	17.3	10.5	9.5	.0	.0	.0
8.00	17.7	19.9	14.6	8.3	.0	28.3	.0	38.1	.0	.0	.0
10.00	12.8	9.6	8.3	5.6	.0	17.0	.0	33.3	.0	.0	.0
12.00	6.8	10.2	.0	.0	.0	7.7	2.6	9.5	.0	11.5	.0
14.00	3.7	7.1	2.1	2.8	.0	2.4	.0	4.8	.0	.0	.0
16.00	1.9	11.4	6.3	11.1	.0	2.4	.0	.0	.0	15.4	.0
18.00	.3	18.3	.0	2.8	.0	1.7	.0	.0	.0	26.9	.0
20.00	.7	1.6	2.1	.0	.0	.0	.0	.0	.0	.0	.0
22.00	.7	1.0	.0	.0	.0	.0	.0	.0	.0	46.2	.0
24.00	.0	.8	2.1	.0	.0	.0	.0	.0	.0	.0	.0
26.00	.0	.6	.0	.0	.0	.0	.0	.0	.0	.0	.0
28.00	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
30.00	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32 +	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Total	572	508	48	36	0	417	38	21	0	26	17

Appendix 15 continued

Winter

Bird code (scientific name in table 2.2)

Height (m)	WARB	WHIT	FANT	SILV	CHAF	RIFL	TOMT	BELL	TUI	PIGE	BLAC
2.00	10.8	.4	4.2	7.9	.0	1.4	12.5	4.0	.0	.0	.0
4.00	20.8	6.9	4.2	1.4	.0	7.9	.0	24.0	.0	.0	.0
6.00	16.2	12.7	4.2	7.9	.0	23.8	6.3	12.0	.0	.0	.0
8.00	19.4	23.2	8.3	18.6	.0	30.0	.0	40.0	21.4	.0	.0
10.00	12.4	18.3	12.5	10.7	.0	14.1	.0	12.0	35.7	.0	.0
12.00	7.8	8.1	12.5	10.7	.0	5.9	.0	4.0	39.3	.0	.0
14.00	7.0	5.6	12.5	17.9	.0	13.1	.0	4.0	3.6	21.0	.0
16.00	3.2	8.1	20.8	15.7	.0	1.4	.0	.0	.0	33.0	.0
18.00	.5	5.8	8.3	7.1	.0	.3	.0	.0	.0	17.0	.0
20.00	.5	4.8	4.2	.7	.0	.7	.0	.0	.0	4.0	.0
22.00	.5	1.7	.0	1.4	.0	1.4	.0	.0	.0	7.0	.0
24.00	.0	1.0	8.3	.0	.0	.0	.0	.0	.0	3.0	.0
26.00	.0	1.5	.0	.0	.0	.0	.0	.0	.0	7.0	.0
28.00	.0	1.2	.0	.0	.0	.0	.0	.0	.0	8.0	.0
30.00	.0	.6	.0	.0	.0	.0	.0	.0	.0	.0	.0
32 +	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Total	371	518	24	140	0	290	16	25	28	100	7

Spring

Height (m)	WARB	WHIT	FANT	SILV	CHAF	RIFL	TOMT	BELL	TUI	PIGE	BLAC
2.00	8.9	.8	13.8	13.0	16.7	4.7	27.3	.0	.0	.0	.0
4.00	21.8	7.1	13.8	7.4	.0	10.6	27.3	.0	.0	1.8	.0
6.00	27.4	24.9	10.3	7.4	8.3	28.8	.0	.0	.0	.0	.0
8.00	12.9	25.3	13.8	13.0	8.3	23.3	.0	3.7	.0	.0	.0
10.00	13.3	7.1	10.3	20.4	16.7	15.7	.0	11.1	14.3	.0	.0
12.00	5.2	5.5	10.3	3.7	41.7	9.7	.0	3.7	.0	.0	.0
14.00	4.4	9.1	10.3	.0	.0	4.7	.0	.0	.0	21.4	.0
16.00	4.0	9.9	6.9	1.9	4.2	1.3	.0	.0	.0	58.9	.0
18.00	.4	4.0	6.9	7.4	.0	.8	.0	14.8	85.7	17.9	.0
20.00	.0	3.6	.0	14.8	.0	.0	.0	48.1	.0	.0	.0
22.00	.8	2.8	3.4	11.1	.0	.0	.0	18.5	.0	.0	.0
24.00	.4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
26.00	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
28.00	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
30.00	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32 +	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Total	248	253	29	54	24	236	11	27	7	56	10

APPENDIX 16

Number of birds counted each month on the contour transects

Transect 1

Bird species code (scientific name in table 2.2)

Month of study	WARB	WHIT	FANT	SILV	CHAF	RIFL	TOMT	BELL	TUI	PIGE	BLAC
November	6	1	11	2	9	2	6	0	0	0	3
December	13	3	21	15	8	2	5	0	0	0	5
January	12	7	14	11	13	2	10	0	0	0	3
February	13	1	17	16	0	8	5	0	0	0	0
March	21	2	18	26	5	3	5	2	0	0	0
April	15	0	20	18	0	9	16	6	1	0	1
May	7	3	13	26	2	4	13	5	0	0	2
June	11	8	13	37	0	5	10	0	2	0	0
July	23	8	8	73	1	7	14	0	0	0	4
August	31	6	20	19	0	9	17	6	1	0	2
September	27	3	21	1	1	2	10	4	0	0	5
October	24	2	14	21	11	6	13	4	2	0	7
November	30	3	19	16	8	0	18	1	0	0	6
December	29	8	17	3	16	8	19	0	0	0	13
January	16	16	20	10	8	7	16	2	0	0	2
February	24	35	20	38	0	15	3	1	0	0	0
March	20	8	22	33	0	14	15	0	0	0	1
April	25	17	24	39	1	10	17	9	0	0	1
May	11	6	18	10	0	3	11	7	0	0	0
June	18	17	14	51	1	7	7	5	0	0	0
July	13	4	5	68	0	2	5	3	0	0	2
August	15	10	14	36	0	1	10	0	0	0	2
September	31	18	28	64	3	1	13	0	4	0	2
October	31	9	12	51	4	1	13	3	0	0	5
November	24	24	24	18	9	8	17	3	0	0	6
December	28	14	23	15	23	5	22	4	0	0	9
January	11	21	27	17	6	13	11	0	0	0	1
February	21	9	16	32	3	7	5	4	0	0	2

Month of study from November 1982 until February 1985

Appendix 16 continued

Transect 2

Bird species code (scientific name in table 2.2)

Month of study	WARB	WHIT	FANT	SILV	CHAF	RIFL	TOMT	BELL	TUI	PIGE	BLAC
November	21	10	2	7	7	7	10	0	0	1	4
December	18	17	1	10	14	11	10	0	0	0	2
January	14	22	1	0	5	15	19	5	0	1	2
February	13	30	3	24	2	14	8	1	0	3	0
March	29	29	2	10	0	14	11	0	3	3	1
April	19	12	6	25	0	4	25	5	5	0	1
May	7	17	7	90	0	10	12	11	1	1	1
June	8	35	8	32	0	13	13	8	4	5	1
July	11	24	1	11	0	11	16	3	1	4	0
August	37	52	3	10	0	15	18	6	1	7	0
September	28	44	3	2	1	6	17	0	1	1	2
October	36	64	0	21	4	3	16	8	0	2	2
November	36	50	2	2	3	12	26	1	0	3	14
December	25	41	1	3	7	15	23	2	0	0	9
January	17	82	5	3	3	17	22	12	1	0	1
February	28	59	8	13	2	23	11	6	0	4	4
March	34	42	13	27	3	12	23	14	9	9	6
April	35	34	9	87	16	10	18	22	6	10	7
May	25	31	5	42	14	15	17	18	1	3	3
June	36	23	1	27	5	12	14	12	5	3	0
July	16	21	4	37	6	10	6	2	5	4	0
August	28	29	1	25	2	10	17	2	4	4	2
September	28	38	11	7	2	11	11	6	2	3	2
October	28	44	3	10	3	15	8	4	0	2	6
November	33	65	0	10	17	16	30	2	0	1	27
December	25	43	0	6	7	12	14	3	1	0	11
January	18	39	14	26	4	27	16	4	1	3	7
February	21	41	8	29	4	23	14	10	7	2	2

Month of study from November 1982 until February 1985

Appendix 16 continued

Transect 4

Bird species code (scientific name in table 2.2)

Month of study	WARB	WHIT	FANT	SILV	CHAF	RIFL	TOMT	BELL	TUI	PIGE	BLAC
November	14	24	0	1	2	7	1	0	0	1	6
December	13	21	0	1	3	8	11	1	0	0	9
January	10	17	0	3	1	4	18	0	0	0	3
February	11	19	0	13	1	11	12	0	0	0	0
March	11	10	0	15	0	8	8	0	1	0	1
April	3	7	2	21	0	10	6	2	0	0	2
May	3	8	0	32	2	7	10	3	1	0	4
June	4	3	0	46	0	18	13	2	1	0	1
July	8	22	0	8	0	11	7	0	1	0	1
August	36	73	2	10	2	15	27	16	0	1	4
September	23	14	0	2	6	7	18	7	3	0	1
October	15	34	0	0	0	8	13	4	0	0	7
November	16	32	0	4	12	6	19	3	0	0	17
December	12	29	0	0	8	9	14	4	2	0	12
January	13	31	2	3	1	7	14	1	0	0	11
February	13	29	0	15	3	5	10	3	0	1	0
March	26	18	0	17	0	12	12	10	0	2	3
April	24	7	0	29	0	11	17	12	0	0	0
May	12	8	1	11	0	1	5	4	1	0	0
June	13	8	1	13	6	6	10	11	0	0	0
July	14	24	0	23	0	3	12	5	0	1	0
August	21	26	0	10	2	9	15	5	0	0	2
September	19	34	0	1	0	4	14	6	0	0	0
October	26	33	0	5	1	4	13	0	0	0	5
November	31	47	1	0	8	3	36	2	0	0	21
December	16	33	0	2	6	5	18	1	2	0	18
January	11	13	0	13	4	10	9	2	3	1	4
February	18	19	2	0	3	15	10	4	2	0	1

Month of study from November 1982 until February 1985

Appendix 16 continued

Transect 5

Bird species code (scientific name in table 2.2)

Month of study	WARB	WHIT	FANT	SILV	CHAF	RIFL	TOMT	BELL	TUI	PIGE	BLAC
November	15	11	0	2	1	5	9	0	0	0	6
December	14	8	3	1	7	11	13	1	1	0	6
January	17	15	0	2	3	21	13	8	0	0	3
February	9	27	0	6	2	17	3	1	0	0	0
March	22	8	0	12	0	12	7	0	2	0	0
April	10	6	1	11	0	14	5	2	0	0	0
May	5	7	2	22	0	9	3	3	2	0	1
June	3	7	3	8	1	16	7	2	0	0	0
July	13	11	1	7	2	20	7	0	0	1	0
August	28	24	1	1	0	17	10	13	0	0	0
September	21	10	0	7	4	8	12	7	3	1	4
October	19	13	1	4	7	10	11	5	0	0	9
November	25	11	1	0	11	8	15	8	0	0	16
December	26	11	3	4	13	14	15	6	2	0	18
January	16	26	1	3	12	15	11	10	1	0	2
February	18	18	1	22	2	17	5	7	0	0	0
March	29	22	6	12	1	13	20	5	0	0	0
April	36	9	3	36	0	15	24	14	0	0	1
May	25	9	2	28	0	10	9	14	0	0	1
June	22	15	0	21	1	3	10	9	1	0	1
July	15	3	1	12	2	10	9	2	1	0	1
August	23	15	1	5	4	11	20	4	2	1	0
September	18	15	3	8	0	6	20	13	0	0	1
October	30	20	3	2	0	3	17	8	2	0	6
November	24	15	3	5	19	9	27	4	1	0	20
December	19	12	2	0	5	9	17	3	0	0	21
January	16	12	0	8	6	21	13	9	0	0	8
February	9	22	0	39	2	17	18	5	0	0	2

Month of study from November 1982 until February 1985

APPENDIX 17

Number of birds observed near/far at each station

STATION	WARBLER		WHITEHEAD		FANTAIL		SILVEREYE		CHAFFINCH		RIFLEMAN		TOMTIT		BELLBIRD		TUI		PIGEON		BLACKBIRD	
	N	F	N	F	N	F	N	F	N	F	N	F	N	F	N	F	N	F	N	F	N	F
1	10	49	15	18	20	61	77	98	7	29	18	2	4	25	0	6	0	1	0	0	0	5
2	32	65	12	50	19	54	28	107	1	24	16	3	14	30	0	10	0	0	0	0	6	13
3	13	29	11	23	31	36	26	46	3	13	18	3	2	34	0	5	0	0	0	0	2	10
4	16	50	14	19	25	44	32	99	2	15	8	3	8	49	0	9	1	2	0	0	1	12
5	11	68	8	20	26	35	18	78	0	14	24	5	6	51	0	11	0	1	0	0	3	10
6	26	51	13	4	10	38	4	50	0	8	26	4	4	24	0	13	0	4	0	0	2	8
7	12	51	4	19	18	34	7	52	1	6	14	2	4	35	0	7	0	1	0	0	2	3
8	14	53	5	28	7	35	5	39	0	9	12	3	8	28	0	8	0	0	0	0	2	5
9	4	75	18	117	1	7	19	60	0	13	59	10	1	57	0	8	1	7	1	2	0	10
10	9	73	31	124	8	8	13	48	0	16	42	8	14	46	0	14	0	6	11	5	1	13
11	6	85	12	158	3	10	5	78	0	22	24	7	16	49	0	32	0	11	7	6	1	14
12	9	66	33	69	8	8	3	52	1	14	48	2	7	33	0	15	0	5	13	2	0	10
13	9	66	16	80	5	13	4	52	0	9	42	5	8	34	2	21	0	6	8	1	4	11
14	17	66	26	80	3	13	15	44	0	12	34	8	12	43	2	19	3	1	8	2	2	17
15	20	65	30	113	10	6	26	78	0	18	33	4	13	37	1	24	1	10	6	2	0	14
16	19	85	11	110	4	15	12	87	2	24	30	7	15	60	2	27	1	6	4	1	1	19
17	14	27	18	23	21	23	17	42	0	8	22	0	6	20	0	5	0	0	0	0	0	2
18	16	75	9	104	12	42	27	106	0	18	31	10	11	65	5	29	1	1	3	0	1	6
19	12	86	25	135	7	37	5	97	1	17	48	18	1	69	2	36	0	8	8	1	0	10
20	7	75	20	141	2	12	12	54	0	18	32	6	14	47	0	30	1	3	11	0	0	13
21	12	67	5	120	3	18	3	34	0	16	15	6	3	50	0	10	0	4	3	2	0	10
22	4	41	7	90	3	1	5	25	0	8	27	4	12	50	0	10	1	4	1	0	2	11
23	8	46	13	84	0	1	5	22	1	5	34	3	11	45	1	5	0	0	1	0	0	5
24	13	27	19	74	1	0	6	21	1	6	15	2	6	36	0	3	0	0	0	0	0	5
25	10	56	4	47	0	0	3	35	2	3	32	7	6	22	2	8	0	1	0	0	0	10
26	8	51	8	94	0	1	8	46	2	8	21	7	8	47	1	9	0	3	0	0	0	10
27	7	42	13	74	0	1	5	35	0	8	44	3	4	37	0	6	0	0	0	0	4	12
28	6	22	11	43	1	0	16	25	0	4	14	5	10	33	4	8	0	0	0	0	1	11
29	4	47	16	49	0	0	1	33	1	4	6	2	13	41	3	10	1	4	2	0	1	18
30	5	49	1	71	0	1	1	22	0	12	35	4	12	44	1	8	0	0	0	1	0	11
31	10	43	1	64	1	1	0	24	1	11	17	5	4	42	1	18	1	1	0	0	0	18
32	7	69	28	119	0	5	4	40	0	15	21	1	3	46	0	29	0	6	3	1	0	37
33	11	60	3	33	3	6	5	45	4	20	42	4	1	35	2	28	0	1	0	0	1	21
34	11	55	2	24	0	3	6	27	0	16	33	3	4	36	1	18	0	1	0	0	0	12
35	12	46	4	21	2	2	0	14	0	9	25	2	2	36	0	26	0	3	0	0	0	13
36	7	47	2	27	1	4	5	29	0	13	34	5	6	39	0	24	1	0	0	0	0	18
37	15	56	4	40	4	4	0	46	0	13	42	8	9	58	0	22	0	3	1	0	1	17
38	10	41	2	54	1	2	8	18	1	10	41	9	10	34	0	8	0	2	0	0	0	12
39	12	51	11	72	2	6	0	33	0	9	38	6	13	24	0	16	0	4	1	0	0	12
40	16	77	16	67	0	2	2	50	1	9	41	8	9	34	0	18	0	3	1	0	0	20
41	4	56	11	69	1	3	3	51	1	20	14	1	4	57	2	25	1	7	1	0	0	28
42	4	37	9	13	0	1	18	40	1	10	2	2	12	42	2	14	0	2	1	0	1	26
43	2	43	0	52	0	0	15	47	1	11	0	2	3	37	0	23	0	6	0	0	3	25
44	1	30	0	8	0	0	7	37	1	10	0	0	3	14	0	13	0	1	0	0	1	21
45	0	25	0	0	0	0	7	37	0	9	0	0	2	13	0	13	0	1	0	0	0	28
46	0	32	0	2	0	0	5	55	0	14	0	0	0	23	0	16	0	6	0	0	1	39
47	0	25	0	2	0	0	4	64	0	15	0	0	0	19	1	19	0	5	0	0	0	29
48	1	17	0	1	0	0	3	31	0	15	0	0	0	11	0	4	0	3	1	0	0	27

N = number of counts within 20m. F = number of counts further than 20m.