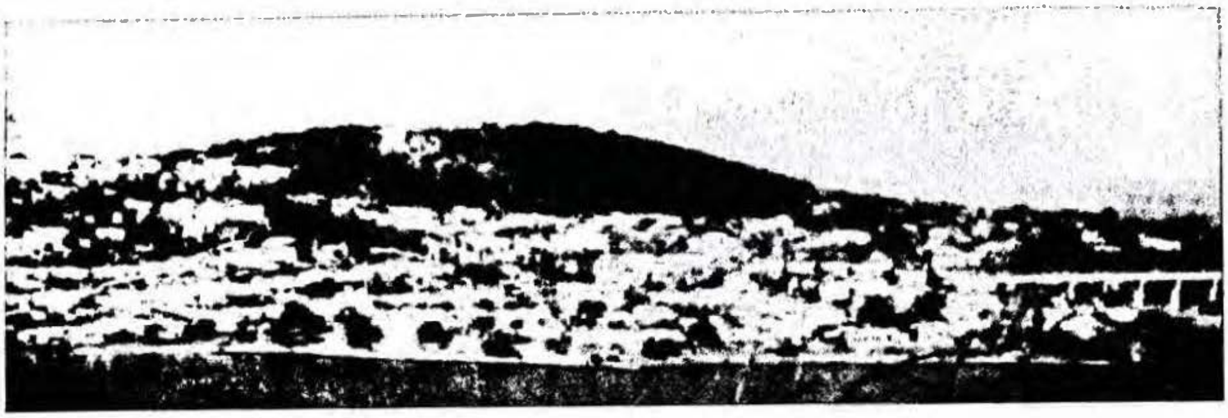
The relationship between woodland remnant size and bird diversity in an urban landscape in southern Tasmania



by

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STATEMENT

This thesis contains no material which has been accepted for a degree or diploma by the University or any other institution, except where acknowledged in the thesis, and to the best of my knowledge and belief, no material previously published or written by another person, except where due reference is made in the text of the thesis.

Photographs on the cover page:

view of Rosny Hill (photograph by the author),

yellow throated honeyeater (photograph by Dave Watts).

Cartoon on the following page by Roger Hargreaves.

ABSTRACT

There has been much research which relates reduction of habitat to reduction in biodiversity and often birds are chosen as the best indicators of these changes. In Australia studies in this area have largely focused on the effects on birds in changing rural or forested, rather than urban, landscapes. There has been little research in this area in Tasmania, yet this State has perhaps the highest proportion of original natural habitat remaining of any State in Australia. This study compared the avifauna of adjacent urban and dry sclerophyll woodland sites in the urban fringe of Hobart and found significant differences in bird species diversity between these habitats.

For the purposes of this study, the woodland remnants, therefore, could be considered islands and were tested for a species-area relationship according to the principles of island biogeography. The varying size of woodland remnant, from 1 to 3100 hectares, simulating 'habitat loss' was used to study its effects on the species richness and population density of the woodland avifauna. Data were gathered by the line transect method in these woodland remnants and the results analysed by the DISTANCE software package which gives estimates of population size and density. The results were plotted as a chart of approximate population sizes of the more common 22 species of woodland bird. Depending on what is considered to be the minimum viable population size the chart could be used as an indication of the threshold remnant area of woodland required for these species. In so doing it provides a mechanism by which predictions may be made regarding reductions in populations and loss of entire species as remnants are reduced further by urban expansion. If acceptable levels of remaining biodiversity for dry sclerophyll woodland can be set, then the sort of methodology adopted in this study could be used by natural area managers to predict whether development proposals are likely to reduce an area of habitat below an ecologically sustainable level.

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And, of course, ...

for the birds.

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Chapter One

Introduction

" ... without changes in land management ...Australia will lose half of its terrestrial bird species in the next century ..." (Recher, 1999: 11).

Studying the relationship between bird populations and habitat change may provide benefits in the form of data for management of natural areas and avifauna, and information about what is happening more broadly across species boundaries. As birds are sometimes considered more vulnerable to habitat alteration than other groups of animals, variations in their diversity, abundance and behaviour may provide indications of environmental change. Therefore, the impact of development of natural landscapes for human use and the resulting effects on biodiversity may be forecast by observing the effects locally on bird populations.

1.1 Background

Many studies have shown that loss of natural habitat generally leads to loss of biodiversity (Mac Nally, 1999; Trzcinski *et al.*, 1999; Villard *et al.*, 1999), although loss for one species may be a gain for another (Recher, 1999). Therefore it is perhaps habitat change that is the significant factor in altering biodiversity. Changes in habitat can be caused by natural or anthropocentric events. During the Earth's history, natural events have shaped the composition of species (Challinor, 1986), with natural extinction, colonisation and evolution of new species resulting in a global balance. Wilson (1989) claimed that the diversity of creatures on Earth has remained roughly constant for many millions of years, even though there have been five major periods of non-anthropocentrically-driven extinctions (Stevens, 2001). In the last few centuries, however, anthropocentrically driven events have increasingly affected species composition, abundance and distribution, if not through direct hunting pressure then through loss or alteration of habitat. It might be argued that species affected would simply move on and find other territories leaving overall diversity unchanged. This may in part be true, but the scale of the changes to natural habitat today and its homogenisation toward human use has limited where those displaced species are able to go. Studies in some States of Australia suggest that this situation is now critical. Bennett and Ford (1997) found that on average only six percent tree cover remained (down from 76% in 1869) in their regional avian study of over 20,000 km^2 in Victoria. Also in a Queensland avian study, it was found that about two thirds of the formerly continuous bushland had been cleared in the last 150 years (Sewell and Catterall, 1998).

Others have argued that it is also the speed of change in loss of habitat that is causing a sixth great extinction episode (Stevens, 2001) where species do not have the mobility to remove themselves from the change nor the time to adapt. According to some, the current extinction rate is 1,000 to 10,000 times faster than before human intervention (Wilson, 1989; Tuxill and Bright, 1998). If this is the case then it is of paramount importance that research attempts to document current biodiversity and monitor changes so that predictions can be made about the effects of future land use changes. Without this knowledge natural area managers can only be reactive - attempting to save species already threatened; instead of proactive - protecting ecosystems for species that are not yet threatened.

Some governments, for example: Australia (ANZECC, 2001) and Britain (UK Government, 1999), are now considering such studies important and since 1992 many countries have signed the Convention on Biological Diversity which highlights the need for research in this area. Long term studies would be particularly useful in monitoring changes to the environment.

At least two Australian ornithologists have separately reviewed the changes to avifauna in long-term urban studies. In Perth between the 1920s and 1995 Recher (1999) found that 55 percent of the avifauna of King's Park suffered significant changes in abundance. A wider scale study in Sydney during a similar period from 1930 to 1994 (Keast, 1995) found 40 percent of bird species had declined in numbers. Both of these studies included local extinctions.

1.2 Using birds as biodiversity indicators

Biodiversity refers to the diversity of all biological life and ecosystems on Earth (ANZECC, 2001), and hence is a measure of environmental health. Since over 1.4 million species have been described, and there are many more not described (possibly 5-30 million - Erwin, 1983), it is hard to estimate biodiversity quantitatively even on a regional scale, let alone continue to monitor changes. The use of indicator species or groups of species to monitor changes in the environment has been widely debated in the literature (Croonquist and Brooks, 1991; Lambeck, 1997; Landres *et al.*, 1988; Noss, 1990). Some of the largest Classes of animals, insects for example, have hundreds of thousands of species, it is therefore, more practical to monitor smaller Classes of animal which are likely to reflect changes in biodiversity generally (Stevens, 2001). Birds are described in just 9,040 species worldwide (Wilson, 1989) and regionally this is often only a few hundred species. This suggests that studying this Class of animal may be a more practical and efficient method of deducing the state of a region's biodiversity. Mammals, although an even smaller group, have characteristics that make their observation difficult whereas birds are one of the most conspicuous groups (Tuxill and Bright, 1998) and are well recognised as good indicators of biodiversity (Pizzey, 1983; Tucker *et al.*, 1997; Wauer, 1997; Hutto, 1998; Marzluff and Sallabanks, 1998; Fendley, 1999). It has been pointed out that land management based on the use of traditional individual bird or even guild indicator species is unlikely to assure the maintenance of all species, but that using a large group such as landbirds will "bring us much closer to maintaining populations of all vertebrates than (using) a select few indicator species" (Hutto, 1998: 81). Canterbury *et al.* (2000) describe further problems with the use of individual bird species and guilds as indicators in that individual species may not represent the guild or that the guild may mask what is happening to indivdual species. Birds may also fail to indicate changes in the environment reliably at the local level where they are migratory species and affected by changes in other areas of their range. The perceived solution in that study was to use bird communities and habitat as the indicators of environmental change.

However, there are many good examples of the use of birds as indicators in the USA (Audubon, 2002; Howe *et al.*, 2002), Canada (Environment Canada, 2002), and Finland (Oksanen, 2000), but perhaps the most significant comes from the current British government using the state of birds, alongside Gross Domestic Product and employment figures, to mark the health of the nation (de Blas, 2001). This assumes a correlation between the health of the avifaunal population and the state of the whole ecosystem in which they live, including all other flora and fauna. If this is the case then the diminishing bird life in Britain over the past few decades should have foretold the deteriorating state of its biological diversity as a whole:

> ... *In Great Britain where the sustained assault on the environment is measured in millennia rather than in centuries, and where most vertebrate species are distant memories, a cascade of invertebrate extinctions is now being observed.* (Murphy, 1989: 72).

Birds also feed on a wide variety of foods (vertebrates, invertebrates, fruit, nectar) and their abundance should therefore be reflected in any significant changes to the environment. Therefore, from the point of view of practical size and broad use of ecosystems, this study uses birds as its indicator of biodiversity.

1.3 Explaining the effects of habitat loss

MacArthur and Wilson's (1963) work on island biogeography attempted to explain why true islands support fewer species than continental areas of similar size and habitat. They proposed that island biodiversity was determined largely by area, but that isolation from the nearest mainland was also an important factor which determined the equilibrium between immigration and extinction.

Diamond (1969), from the results of his study of island birds off the coast of California, confirmed the view that no island supported as many species of birds as it would have if it were part of the mainland. For comparison, Tasmania supports fewer species of birds (approximately 228) than an equivalent area of Victoria (eastern Victoria 360, western Victoria 389) just across the Bass Strait (numbers of species deduced from *'The Field Guide to the Birds of Australia'*, Pizzey, 1997).

In 1975 Diamond built a set of principles on this theory relating to minimising extinction rates. The first principle was that large reserves can hold more species than small reserves. A reserve being an 'island' of natural habitat surrounded by less desirable habitat. Many researchers since have used this

1.4 *Where is the loss of habitat in Australia?*

Table 1.1 is derived from Stevens' report for the Commonwealth Government on declining biodiversity and highlights where native vegetation has been cleared

to 20,000 hectares a year (Forest Practices Board, 2000), although small in terms of Australia's total land clearance, is a significant proportion of the remaining natural vegetation of the State itself (about one percent per year) and the highest proportional rate of any State in Australia. Much of this clearance is due to forestry practices and Bosworth *et al.* (1976: 79) warned that "practically all the lowland dry sclerophyll forest lies within the woodchip concession boundaries". Lowland dry sclerophyll forest is, therefore, a habitat type that has been subjected to degradation in Tasmania for decades and a proportion of this loss is due to urban expansion.

Table 1.1 Australian native vegetation clearance for 2000 (Stevens, 2001).

State	Area (ha)	Clearing as % of State area	% of total clearing in Australia
Queensland	425,000	0.246	75.2
NSW	100,000	0.125	17.7
Tasmania	**17,000**	**0.251**	**3.0**
N. Territory	12,700	0.009	2.2
WA	6,000	0.002	1.1
Victoria	2,500	0.011	0.4
SA	1,600	0.002	0.3
Total	**564,800**		

1.5 *Why an urban study?*

An increasing human population, consuming more and more of the Earth's resources and original natural habitat, is leading to loss of habitat and biodiversity (Suzuki, 1998). The growth in urban centres is occurring at an even faster pace than human population growth yet scientific interest in the effects of this on the natural environment has long been neglected (Collins *et al.*, 2000). An understanding of the urban environment from an ecological perspective is therefore essential if the majority of the human population is going to live alongside nature instead of in place of it. Uhl (1998) suggests that it is this very connection with the land on our doorstep that creates the first love of the earth and hence is the first step towards living sustainably.

To identify threats to biodiversity conservation in Australia's ecosystems and remnant vegetation, ANZECC states that the highest priority for research at both local and regional levels is in the areas of "fire regimes, urban sprawl, water resource allocation, dryland salinity, weeds and feral (species), agriculture, grazing, mining, ... and changed climate patterns" (ANZECC, 2001: 50). As a high percentage of people live in the urban environment (in Australia this is estimated to be 85%), habitat at the fringes of cities is perhaps most under pressure and is deserving of more attention. Hobart, Tasmania is one such city in Australia and one of its dominant surrounding ecosystems is dry sclerophyll (eucalypt) woodland, some of which supports the nationally endangered swift parrot and the forty-spotted pardalote (one of the rarest of Tasmania's endemic species). This study, therefore, focuses on this important habitat type.

1.6 Surveying techniques

Two articles by Emlen (1971, 1977) and three books (Davies, 1984; Bibby, *et al.* 1993; Buckland *et al.*, 1993) gave adequate examples and descriptions of bird surveying techniques.

Bird surveys are usually carried out by one of four main methods. The simplest is the SPOT transect. This is carried out with the observer standing in one spot and searching a known distance in all directions, thus covering a known area over a fixed period of time, random spots being sampled over the chosen areas to build up a picture of population density of the species of interest. STRIP transects are similar except that the observer moves slowly along a path of known length and searches a certain distance either side. This covers a known area and therefore, assuming that the species in question is evenly distributed across the whole site of interest, a figure for population density may be calculated. More extensive AREA searches may be undertaken if a detailed single species study is required. Finally a development of the strip transect is the LINE transect method. This is essentially the same as for strip transects , but it assumes that not all birds will be found during the transect. Emlen had shown three decades ago that each bird species had a different "coefficient of detectability" and how to calculate it (1971: 327-331). Modern LINE transect theory (Buckland *et al.*, 1993), based partly on Emlen's work, uses the perpendicular distance from the transect line of each object of interest to deduce, by statistical analysis and mathematical modelling, figures more closely related to absolute population densities.

Line transects were chosen for this study because more time could be spent sampling rather than travelling between points in point surveys and they are considered to be less susceptible to bias with fewer detections required for precision. LeMar *et al.* (2001) also considered that: "Line transect sampling is recommended over strip transect sampling for estimating species abundance when more than one species or habitat are of interest", in their survey of nocturnal macropods in forests in Tasmania.

Casagrande and Beissinger (1997) in their study to estimate the population of the green-rumped parrotlet in Venezuela, compared four censusing methods (point and line transects, mark-resighting and roost surveys) and concluded that, since the detection probability was more variable for point transects than for line transects, the latter method gave the most accurate results and hence was the best method where conditions allowed. Occasionally line transects are not possible due to the terrain or habitat, but in this study based, in open grassy woodlands in southern Tasmania, line transects appeared to be the best method. The mark-recapture method of assessing populations of birds is highly labour-intensive and not suitable for a one-person, one year study.

From these recommendations it was decided to use the line transect survey method for this study. The methodology presented in this study could be used in a wide range of future studies where population and diversity of species are the critical issues. As an example, Ford *et al.* (2001) suggest that there have up to now been no effective studies of the control of cats in relation to the survival and population of birds. The methodology described would provide a simple means to estimate the absolute population of birds in such a study.

1.7 Hypothesis

There have been a number of different approaches adopted in urban bird studies ranging from those based on: natural-to-urban gradients (Huhtalo and Jarvinen, 1977; Bolger, *et al.*, 1997; McDonnell *et al.*, 1997); distance to nearest native forest (Catterall *et al.*, 1989); studies of the effects of temporal changes in bird communities as the level of urbanisation increases (Geis, 1974; Jones, 1981; Keast, 1995; White *et al.*, 1996; Fuller *et al.*, 1997; Recher, 1999); while others have looked at the effects of differences between urban and non-urban environments on bird communities (Emlen, 1974; Beissinger and Osborne, 1982); studies where the focus is on the spatial structure of the remaining natural landscale within the urban environment (Roth, 1976; Fahrig and Merriam, 1994); but perhaps the most beneficial approach has been the use of habitat-island theory in the urban context (Soule *et al.*, 1988; Adams and Dove, 1989; Fernandez-Juricic and Jokimaki, 2001).

Adopting the latter approach, this study is based on the principle that as natural habitat is fragmented and lost to urban expansion so too is much of the diversity and population of the original suite of species. More specifically, this study focuses on the avifauna of remnants of dry sclerophyll woodland in the expanding urban environment of Hobart, Tasmania, in an effort to determine whether woodland bird species richness and abundance decline with urban expansion and reduction in remnant size. If this is supported by the results then it will be of interest to determine whether species richness and density are reduced proportionately with remnant area or whether there is a threshold area below which some species are absent.

1.8 *Project aims*

This project aims to:

- compare bird species diversity found in woodland remnants with adjacent urban habitat,
- test whether these remnants act like islands in terms of island biogeographic theory based on their avian diversity,
- test whether there is a relationship between number of species and area of remnant,
- estimate the population density of the more common woodland bird species over the range of woodland sites,
- plot population estimates for the remnant sites to determine if viable populations can exist only above a certain area, and
- provide a local baseline avian biodiversity study upon which further monitoring can continue.

Chapter 2

Methodology

"...managers should not try to measure fragmentation, but instead should focus on determining how much habitat is available and whether it is enough to support a population of the species of interest." (Trzcinski *et al.*, 1999).

2.1 *Time frame of the study*

This study spanned the period January 2001 to June 2002. Approximately twelve months of this was available for the study. Three months were spent in the field visiting the selected sites during three periods: winter (late May to early September); spring to early summer (early October to December); and late summer to early autumn (February- early March). This was to cover all migrant bird species, both summer and altitudinal, as well as resident species.

The early part of the study period was spent reviewing literature: books, journals, electronic journals and internet resources on research in this area and to assess different methods of approaching the fieldwork aspect of this study. Contact was also made with local experts in the areas of bird observation, natural area management, local vegetation and researchers undertaking similar studies. Birds Tasmania meetings also provided contact with people with a wealth of local ornithological experience.

2.2 *The sampling design*

A surveying system based on the line-transect method (see Chapter 1.6) was adopted to collect data for analysis by the computer pro

(Buckland *et al.* 1993). DISTANCE was written specifically for biological population studies. It uses either point or line counts of birds and the distance from the observer to allow estimation of the probability that all birds were detected. Mathematical models are then fitted to the results to be able to estimate population densities. As it requires 60 to 80 sightings to accurately determine population density this was only attempted at the analysis stage for the more numerous species.

2.3 *Site selection*

Potential isolated woodland remnant sites were selected by studying the 1:25,000 map of the Hobart area (Department of Lands, Parks and Wildlife, 1988); 1:5,000 aerial photographs and GIS maps of the vegetation communities supplied by the local councils. Many likely areas were then visited to assess their current status. Some isolated remnants of bushland shown on the map had since been developed especially to the west of the Derwent River, but east of the river there are a number of suitable patches. Those selected are listed in Table 2.1. The first six are in the urban zone and therefore adjacent street transects were selected for the initial urban/woodland comparison. The last two woodland sites, Mount Rumney and the Meehan Ranges, were expected to act as 'control' sites allowing the smaller sites to be compared with the larger, more undisturbed ones. A one-year study by a single observer constrained the number of sites to this minimum to carry out a useful study.

Access was generally simple since only one site, Rokeby Hills, was private. However, it has an extensive network of publicly accessible tracks. At Mount Rumney, although the State Recreation Area is very small, access to a large private block was obtained to extend the sampling area.

These areas were investigated in an effort to match the potential transects at the different sites for similar vegetation, aspect and altitude. This was to try to reduce the variables as much as possible so the main comparison would be in habitat size rather than be confounded by other influences.

Table 2.1 Attributes of the woodland sites selected for this study

Woodland Site	Area Hectares	Altitude Metres	Urban St. Site	Latitude South	Longitude East
Warrane	1	80-100	Binalong St*	42°51′44″	147°23′00″
Rosny	14	40-94	Ninda St	42°52′14″	147°21′28″
Natone	46	50-128	Raminea St	42°50′48″	147°20′43″
Gordon	52	70-140	Kaoota St	42°51′32″	147°21′48″
Mornington	82	70-160	Binalong St*	42°52′08″	147°23′23″
Rokeby	160	50-150	Elinga St	42°53′54″	147°25′09″
Mt Rumney	800	290-380	none	42°51′44″	147°27′12″
Meehan	3,100	80-280	none	42°50′34″	147°23′55″

See maps (Figures 2.1 to 2.9) for details. * Warrane and Mornington woodland sites were compared with the same street transect.

Each of the sites below 60 hectares in area (Warrane, Rosny, Gordon and Natone) were all selected primarily because they were islands of relatively natural vegetation surrounded completely by the built environment. Mornington is hemmed in by residential developments on three sides and by the relatively new South Arm Highway which divides Mornington from Knopwood Hill to the east. Rokeby, the next largest site at approximately 160 hectares, has suburbia to the west and agricultural land to the east. The Rokeby Road divides it from the Knopwood Hill area to the north and to the south it is isolated by the bare grassy hilltops of Droughty Point.

The Meehan Ranges to the north of the Tasman Highway form one of the largest remaining tracts of dry sclerophyll forest and woodland in the region. It covers an area of approximately 6,000 hectares, about 3,100 hectares of which form a reasonably continuous block of woodland bounded by the Grasstree Hill

Road to the north and the Tasman Highway to the south. There are a few significant disturbed patches such as the Flagstaff Gully Reservoir and quarry area and the Risdon Vale community.

2.4 Development of transects

In the woodland sites transects were located at least fifty metres from the edge to avoid the 'edge effect' as much as possible and, therefore, give a good representation of birds of that habitat type. However, in the smallest site of Warrane (one hectare) this could not be achieved. The transect was kept as far from the edge as possible (approximately thirty metres).

All of the woodland sites are hilly and therefore transects were selected to cover both ridge and valley and differing aspect within a site as much as possible, for example, both the north facing and south facing slopes. Transects were also selected to cross as many of the dominant vegetation types as possible in the sites up to 200 hectares, where access permitted. In the larger areas (Mount Rumney and Meehan Ranges), transects were located as much as possible to pass through vegetation types similar to those in the smaller sites to reduce the potential confounding effect of variability in vegetation.

Once the woodland sites had been selected, streets were chosen at random for the urban transects. These were selected to be at least 100 metres away from the woodland edge, again to avoid the edge effect, and were generally around 200 to 300 metres away from their adjacent woodland transects at the nearest point. The urban transects were wide streets with a few trees, garden shrubs and lawns and the transect length was set at 300 metres to give a reasonable coverage.

In the urban sites transects were walked along the footpath on one side of the street with the centre line of the road being considered the line from which the transect width was measured. As a rudimentary comparison between urban and woodland sites it was decided to use established paths in the woodlands for the majority of transects. This reduces the random nature of the transect selection, but has an advantage in that it reduces the likelihood of disturbing birds before the observer has located them (response to observer movement can give imprecise estimations of the probability of detection of animals at the analytical stage). In a pilot study to determine macropod densities in woodlands in northern Tasmania, Le Mar *et al.* (2001) had discovered that problems were faced when animals responded to observer movement and, therefore, to reduce this problem the researchers cleared the transect lines. Other field studies of these survey methods have shown that line surveys are more reliable than point surveys in open habitat, but that moving through dense habitat can be a problem (DeSante, 1986; Bollinger *et al.*, 1988). Generally the dry sclerophyll woodlands in this study were of the open grassy type and where there was dense undergrowth or dry leaf litter on the ground it was quickly realised that walking transects through this created a disturbance. Dense undergrowth also impeded vision. Although paths were used in this study there was generally still some canopy and hence the path itself did not create a barrier to the movement of birds. Catterall (2000) considers that a gap of less than twenty metres "does not constitute a break in continuous connection" unless, it is a large area (more than 300 hectares) and "divided by a road or cleared easement or other barrier".

Choice of transects was therefore a compromise between: keeping away from the edge zone; covering all vegetation, aspect and altitude within a site; random selection and reducing noise disturbance. Since established paths were chosen, however, they were readily comparable to the street transects and since the criteria for woodland transect selection was constant across all sites, comparison between the woodland sites was also possible.

2.5 Variables measured along the woodland transects

- Two 300 metre transects were selected for each woodland remnant except in the case of the smallest site at Warrane (one transect of 200 metres) and the largest site in the Meehan Ranges (three transects of 300 metres). Transect length along with number of transects traversed determined the amount of effort per site, important in calculating the population density figures.
- Approximately 50 metres either side of the line were studied giving an area of study of three hectares per transect. In DISTANCE analysis the width of the transect is not important.
- Time taken per transect was measured. This ranged between 30 and 45 minutes depending on factors such as vegetation density, ease of walking the transect and how many birds needed to be identified and recorded.
- Sites were visited between three and five times per season. This gave an on-site-time of around five hours per site per season, that is at least fifteen hours per site over the course of this study which is well beyond Slater's recommendation of "at least two hours per site over several visits" (Slater, 1994) for good coverage.
- Surveys were undertaken from approximately 8am to 3pm. This avoided the initial daily burst of avian activity at sunrise and also avoided the disturbance caused by human activities later in the day. Times of site visits were varied to cover species of birds singing at different times of the day.
- Observations of all birds seen or heard and cluster size (number of birds of one species seen together in a group at one time, usually one) were noted on a specially designed Survey Sheet (see Table 2.2). More effort was focused on identifying birds on or near the transect line since an assumption made by DISTANCE analysis is that all animals of interest on the transect line are detected with a probability close to 1.0. Perpendicular distance of each bird from the transect was estimated, with estimations regularly checked by pacing out the distance to where a bird had been identified. The distance along the transect of each observation and whether the bird was to the left or

right was also noted on the Survey Sheet (for example, see Table 2.2) for possible mapping of individual bird territories later.

- On each survey sheet a record was made of the prevailing weather conditions: temperature, approximate wind speed and direction, cloud cover, sun/rain.
- Other information gathered where possible was: the type of vegetation in which the bird was seen, the height at which it was seen, whether there were any signs of breeding or nesting and any interesting inter- or intra-species behaviour.
- Other species seen within the remnant visited and at least fifty metres from the edge, but outside of the transects were also noted.
- Information was later entered into an excel spreadsheet prior to importing into the DISTANCE database.

Table 2.2 An example of a specially designed survey sheet

	Study Area		Length	Direction	Start time	End time		Date	Data entered		Transect
	Mornington		300	S>N	1135	1215		17.10.01	04.11.01		T1
	Temp	14	sun x	cloud	100%	Wind	SE2	rain x			
No.	Species	h?	Total No.	Pair	Nesting	Perp dist	to	Height	Vegetation	Paces	Notes
1	BWP		1			2	L	mid	Ev	20	at end of dead branch
2	FRA		2			0		flying		0	
3	BT	h	1			20	R			47	rain
4	STP	h	1			10	R			70	
5	BT	h	1			10	L			70	
6	GF		1			25	R	top	Ev	95	
7	DWS		1			20	L	flying		100	
8	BHH		1			50	L	top	Eam	100	
9	GF		1			20	L	mid	Eam	110	
10	DWS		2			0		flying		152	
11	GF		2			0		mid	Eam	125	
12	STP	h	1			10	R			130	
13	ML		2	pr		0		mid	Ev	160	investigating holes
14	BFCS		1			0		high		120	
15	DWS		1			0		flying		150	
16	HBC		1			?	L	mid		210	desc "tseeeuw"
17	DWS		1			10	L	high	Eam	160	
18	BFCS		3			0		flying		160	
19	DWS		1			10	L	mid	dead E	200	
20	HBC		1			10	L	mid	dead E	257	flew off (same as 16?)
21	YTH		3			0to10	R	low		257	chasing off HBC
22	ER		1			0		flying		280	alarm call
23	BHH		2			0		low	wattle	260	
24	BHH		1			10	R	high	Eam	260	
25	GST		1			5	R	high	Eam	260	
26	STP		1			5	R	high	Eam	260	
27	ER		1			3	R	high	big dead E	330	at top of hill

In column three "**h**" denotes that the bird was heard only. NB, one pace = 0.9 metres.

2.6 Species included

Thomas (1979) lists 59 species of birds that utilise dry sclerophyll woodland in Tasmania, this includes four nocturnal species, five exotics and 15 species for which it is a secondary habitat type. In this study a further nine species were seen utilising this type of woodland on at least one occasion. However, as this was a study of diurnal woodland birds no data were gathered on the nocturnal species; and gulls, waterbirds and waders were not included. Two more exotic species (spotted turtle dove and house sparrow), which are found in the urban areas, were also added to the potential list making 66 species in all (59 native species) likely to be recorded on the transects.

2.7 Data analysis

The first stage in this analysis was to determine the species accumulation curve for each site. This is a useful method of assessing whether sufficient visits have been made to observe the majority of species present (Coddington *et al.*, 1996; Bennett and Ford, 1997; Moverley, 1997; Minckley *et al.*,1999). Without this assurance the comparison of species richness between sites would be of little value.

Two computer software packages were used in this study. PATN (Belbin, 1993) is a computer program written for the exploratory analysis of ecological data, and DISTANCE (Buckland *et al.*, 1993) a sampling technique used to estimate the density or abundance of biological populations.

PATN uses algorithms to estimate association, cluster, ordinate and network objects of interest. In this study the Bray-Curtis type of association was used in the generation of estimates of association between pairs of objects. Hierarchical agglomerative cluster analysis was then used to produce the UPGMA dendrogram of the relationship between bird populations and the study sites. TWINSPAN (Hill, 1979) is a program for two-way indicator species analysis which (in this case) was used to classify the bird species based on the sites where they were found, and the sites based on the bird species found at each site. It presents the results in an ordered two-way table (see Figure 3.15). PATN also uses a general purpose multi-dimensional scaling (MDS) algorithm to produce two-dimensional ordination plots. This was used to display the relationships between the study sites based on their bird assemblages using the principle axis correlation (PCC) program in the evaluation mode of PATN. PCC is a multiple linear regression program designed to determine how well a set of variables can be ordinated and if species data is responding in any systematic way to environmental attributes. It also produces a correlation coefficient of the fit to the ordination for each attribute.

DISTANCE (Buckland *et al.*, 1993) was used to estimate bird species population and density using line transect methodology. Initially the entire data set of woodland bird observations was compiled into one large text file for importing into the DISTANCE software package. DISTANCE constructs probabilities of detection of objects at various observed distances in order to determine population density estimates. Since outlier observations provide relatively little information about density, but are always difficult to model it is recommended that data are truncated to exclude the outlying observations (often only 5-10% of the sample), this simplifies the modelling of the probability detection function upon which object densities are calculated and hence makes for more accurate density estimates. Data based on the number of birds detected and the perpendicular distance at which they were observed from the centre line of the line transects were used to determine a probability of detection function for each species at each site. A probability of 1.0 means that the species will be seen within the transect area with 100% certainty and where this is the case it means the line transect is effectively a strip transect and therefore the calculation of density is based simply on the number of individuals detected. Where DISTANCE calculates a probability of detection of less than 1.0 the density estimates are adjusted accordingly and hence sightability is taken into account making the density estimates more accurate than those calculated by the strip transect method. In strip transects using narrower strips for the transects increases the likelihood that all birds will be seen, but reduces the sample size and therefore the precision. Increasing the width should lead to better precision, but since a reduced percentage of the birds will be detected the density will be underestimated (Buckland *et al.*, 1993; Casagrande and Beissinger, 1997; Le Mar *et al.*, 2001).

Bias due to evasive movement away from the observer and undected clusters near the transect line was checked by investigating the histograms of distance data which DISTANCE produces in its calculations. To avoid counting birds more than oncetheywere onlyrecorded at their initial locations and by keeping an awareness of birds already detected moving ahead of the observer they were not counted again. Walking the transect at a reasonable pace also facilitated counting birds only once.

2.8 *Vegetation*

Potential sites for study were chosen from the satellite and GIS vegetation maps supplied by the Clarence City Council (de Gryse *et al.*, 1995), see Figures 2.1-2.9. Similarity in vegetation structure was the main parameter used in choosing transects, the suitability of which was confirmed after visits to each site. The vegetation profile was assessed at three levels: dominant trees (over 7 metres), understorey (1 to 7 metres) and ground cover (< 1 metre). For each transect, depending on vegetation consistency within the site, one to two 20x20 metre quadrats were checked for stem density by counting large stems over 50 centimetre in circumference and also any other stems over 2 centimetre in diameter as a relative comparison between sites. These are listed by species and are shown in Appendix VII as stem density per hectare. Height, canopy cover and health were recorded for the dominant eucalypts. Also a Bitterlich wedge count, a simple measure of tree volume, was made at each transect using the "Bitterlich Variable Radius Method" (Mueller-Dombois and Ellenberg, 1974) to be able to compare stem basal area between sites. Finally a representative sample of ground and understorey plants was taken at each quadrat and from that a species list was created for each site (Appendix VIII). This was to further test the similarities or differences of the sites in question. See Table 3.7 which summarises the information in Appendices VII and VIII.

2.9 *Study sites maps*

The following pages show the study area and individual sites, highlighting the dominant woodland vegetation communities and the approximate positions of the transects.

Figure 2.1 Clarence City Council area study sites

Site 1	Warrane
Site 2	Rosny
Site 3	Natone
Site 4	Gordon
Site 5	Mornington
Site 6	Rokeby
Site 7	Mount Rumney
Site 8	Meehan

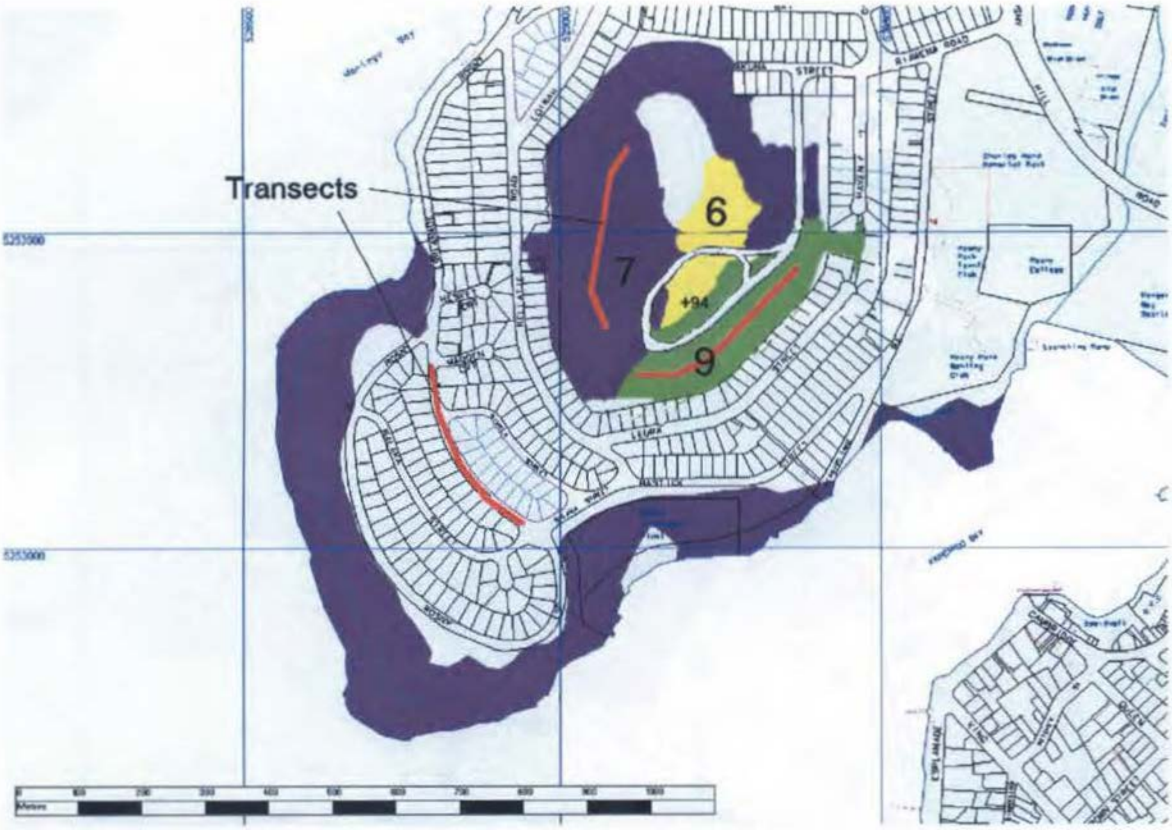

Figure 2.2 Rosny

Dominant Vegetation Community

6. Native grassland
7. She-oak forest/woodland
9. Grassy *E. viminalis* woodland/forest

Jurisdiction State.

Area (1998 aerial photo) 22 ha total, 14 ha woodland.

Perimeter 1.8 km external, 0.8 km internal.

Nearest larger neighbour 0.75 km.

Further observations

Obvious signs of wood-gathering, dogs off the lead, cats roaming, road to hill-top used as a 'race-track'.

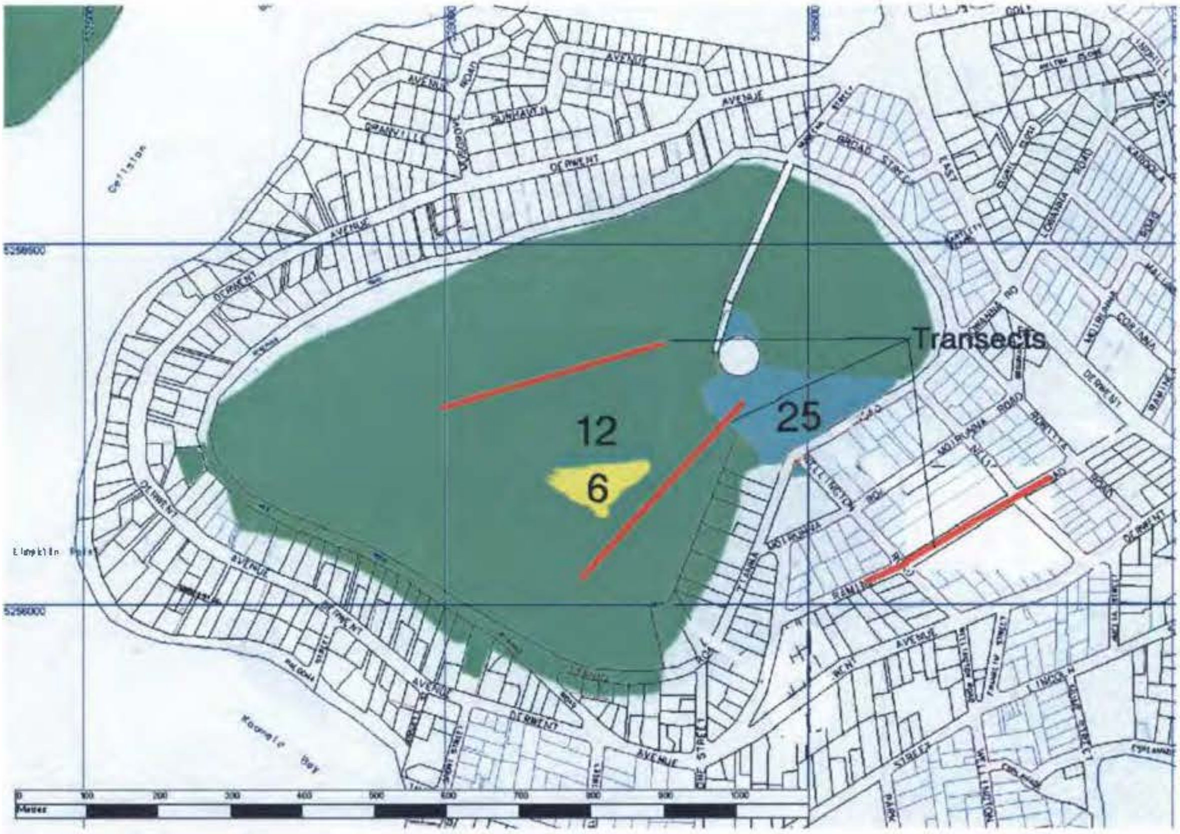

Figure 2.3 Natone

Dominant Vegetation Community

6. Native grassland
12. Grassy *E.viminalis/E.amygdalina* woodland
25. Shrubby *E. globulus* forest

Area (1998 aerial photo) 47 ha total, 46 ha woodland, 0.5 ha grass, 0.5 ha other.

Perimeter 2.75 km external, 0.5 km internal.

Nearest larger neighbour 0.5 km.

Jurisdiction Clarence City Council.

Further observations

Many of the large trees, particularly the few *E. globulus*, are dead or in poor condition. Cats seen roaming. Subjected to a regular fire regime.

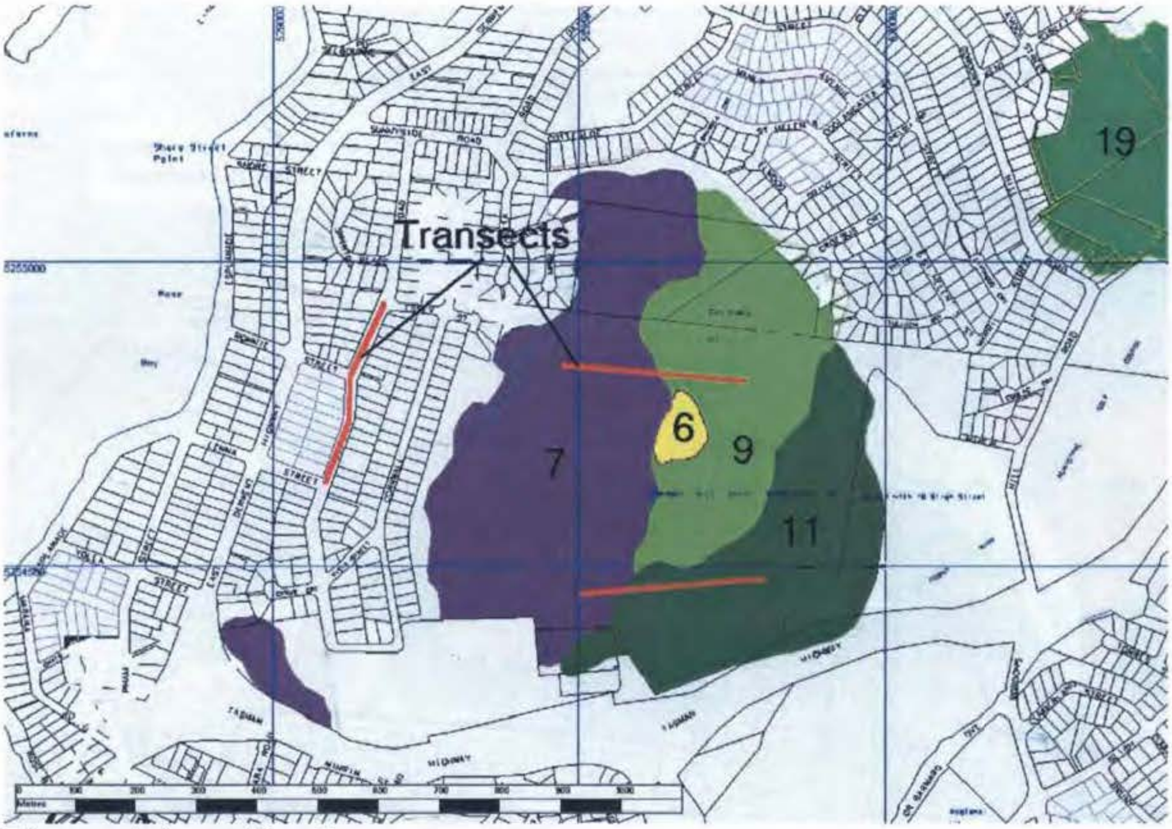

Figure 2.4 Gordon

Dominant Vegetation Community

6. Native grassland
7. She-oak forest/woodland
9. Grassy *E. viminalis* woodland/forest
11. Grassy *E. globulus* forest

Jurisdiction Clarence City Council/State.

Area 53 ha total, 52 ha woodland, 1 ha grass.

Perimeter 2.9 km external, 0.3 km internal.

Nearest larger neighbour 1.0 km.

Further observations

Many of the large trees particularly the *E. viminalis* are in poor condition. There was a fire alongside the transect from above Essex Street to the grassy summit in January or February 2002. There are signs of trail bike damage on some of the tracks and around the large old *E. viminalis* at the summit.

Figure 2.5 Mornington (and Warrane)

Dominant Vegetation Community

7. She-oak forest/woodland
(11. Grassy *E. globulus* forest.)
(12. Grassy *E. viminalis/E. amygdalina* woodland/forest.)
13. Grassy *E. amygdalina* woodland/forest
14. Grassy *E. ovata* forest/woodland
19. Heathy *E. amygdalina/Allocasuarina littoralis* forest.
(22. Grassy/shrubby *E. risdonii* forest/woodland.)
(25. Shrubby *E. globulus* forest.)

Jurisdiction	Clarence City Council.
Area (from 1998 aerial photo)	83 ha total, 82 ha woodland, (Warrane 1 ha).
Perimeter	4.7 km (Warrane 0.54 km).
Nearest larger neighbour	0.1 km (Warrane 0.3 km).

Further observations

A fire was lit by the fire brigade on the southern side of Mornington Hill on 6th March 2002, a day chosen to do observations, by the 26th March the entire ground and shrub layer of the eastern half of Mornington Hill had been burned. There are signs of trail bike damage on some of the steeper tracks and near the summit just below the watertank.

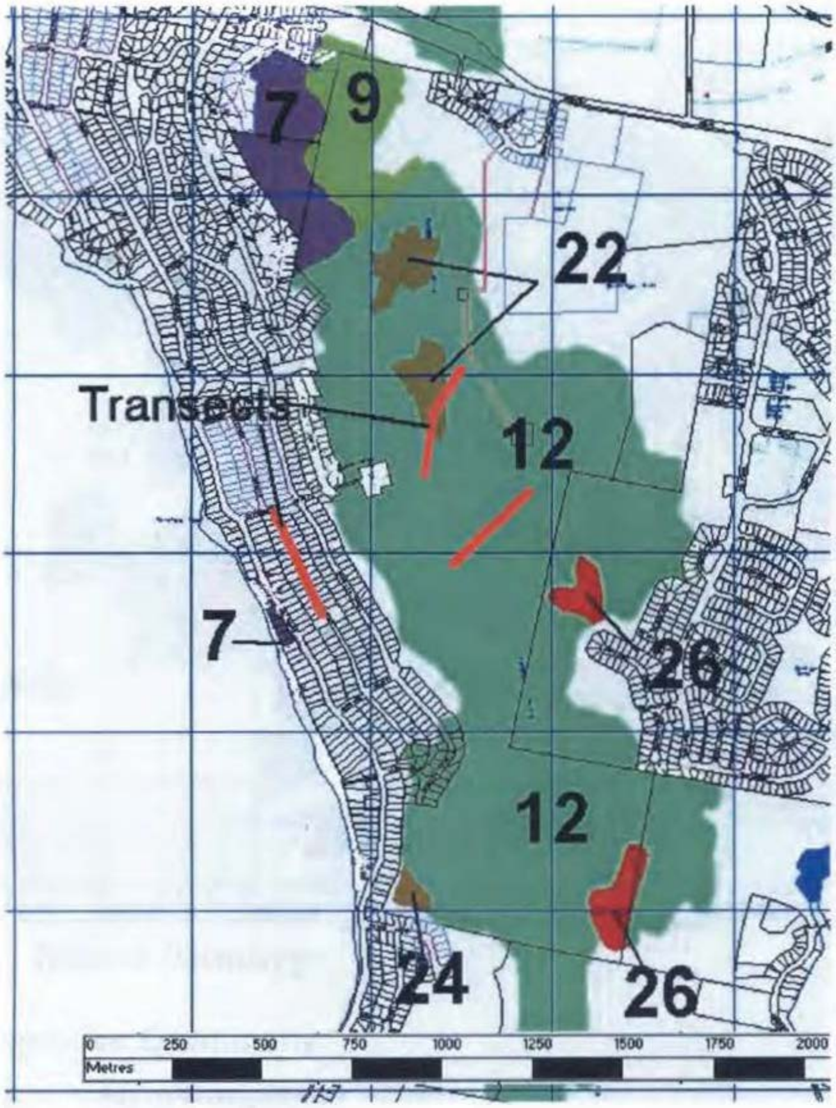

Figure 2.6 Rokeby

Dominant Vegetation Community

7. She-oak forest/woodland
9. Grassy *E. viminalis* woodland/forest
12. Grassy *E. viminalis/amygdalina* woodland/forest
22. Grassy/shrubby *E. risdonii* forest/woodland.
24. Shrubby *E. ovata* forest (no longer exists).
26. Shrubby *E. obliqua* forest (DRY/WET)

Area (1995 aerial photo)	160 ha.
Perimeter	7.0 km.
Nearest larger neighbour	2.5 km.
Jurisdiction	Private.

Further observations

There are signs of trail bike damage on some of the tracks. Feral cats seen.

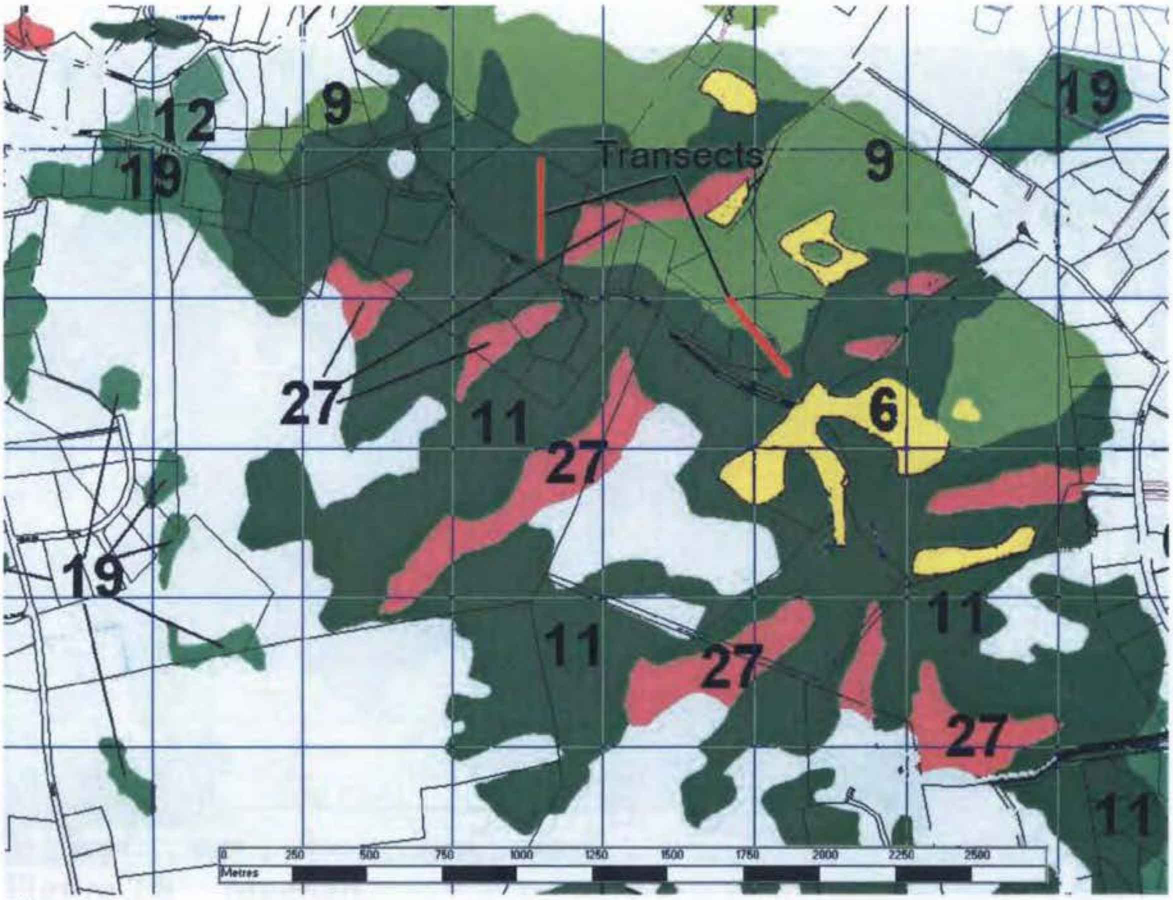

Figure 2.7 Mount Rumney

Dominant Vegetation Community

6. Native grassland.
9. Grassy *E. viminalis* woodland/forest.
11. Grassy *E. globulus* forest.
19. Heathy *E. amygdalina/Allocasuarina littoralis* forest.
27. *E.globulus* wet schlerophyll forest.

Jurisdiction Mostly private, part State.

Area (1988 1:25,000 map) 850 ha total, 800 ha woodland.

Perimeter 16 km external, 5 km internal.

Further observations

Some large trees with hollows. Disturbance at the summit from cars, much rubbish on the ground in the State Recreation Area.

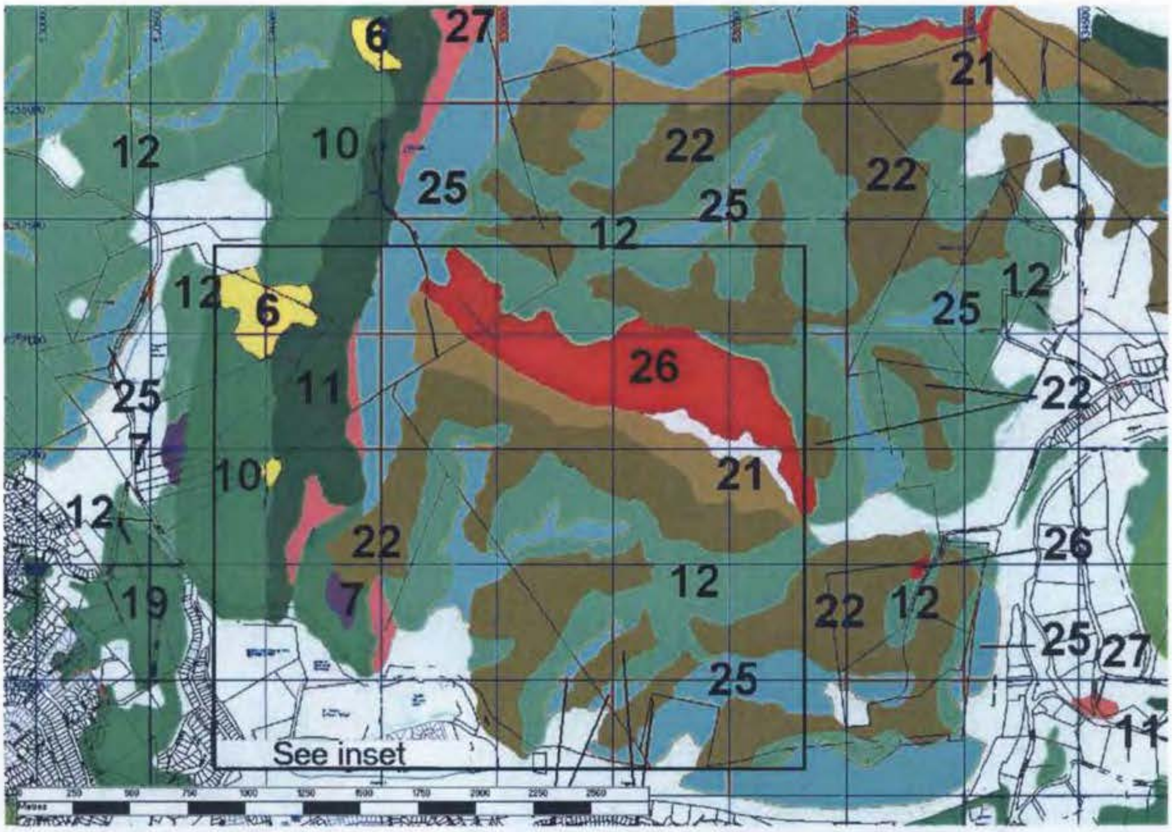

Figure 2.8 Meehan

Dominant Vegetation Community

6. Native grassland
7. She-oak forest/woodland
10. Grassy *E. pulchella* woodland forest
11. Grassy *E. globulus* forest
12. Grassy *E. viminalis/E. amygdalina* woodland
19. Heathy *E. amygdalina/Allocasuarina littoralis* forest
21. Grassy/shrubby *E. tenuiramis* forest
22. Grassy/shrubby *E. risdonii* forest/woodland
25. Shrubby *E. globulus* forest
26. Shrubby *E. obliqua* forest (dry/wet)
27. *E. globulus* wet schlerophyll forest

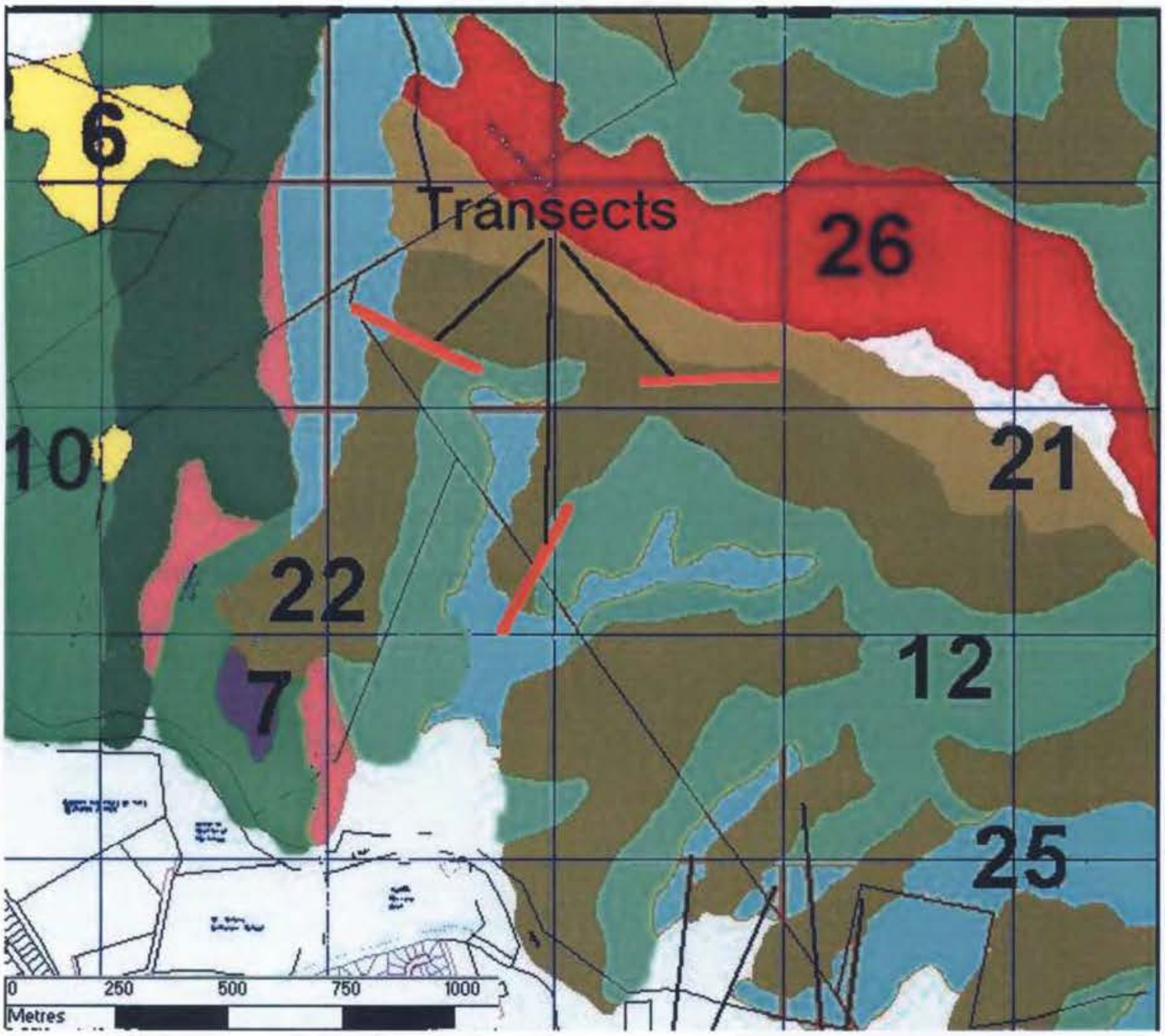

Figure 2.9 **Meehan - inset**

Jurisdiction Private/State.

Area (1988 1:25,000 map) 3,100 ha (6,100 ha including area north of Grasstree Hill Road).

Perimeter 28 km (59km)

Nearest larger neighbour 8 km.

Further observations

Apart from the shooting range near the western transect and a few cyclists there appears to be little disturbance, although trail bikes are ridden in the vicinity of the quarry area.

Chapter 3

Results

"... *the perfect bird count probably does not exist, but this need not prevent the extraction of useful results from a good study* ..." (Bibby *et al.*, 1993).

3.1 The raw data

This study is in two main parts. Bird species composition and abundance were compared: firstly, in six adjacent woodland and urban sites in winter and spring; and, secondly, across a range of eight woodland sites of different sizes in winter, spring and summer. Data from each individual survey sheet, of which Table 2.2 is an example, was collated in an excel spreadsheet. This forms the raw data upon which all further quantitative analysis is performed. Appendices I to V show the accumulated totals of all species of native and introduced birds seen or heard at each woodland and urban site, by season. Note that wherever bird common names have been abbreviated in the text to two to four letter codes the reader should refer to Appendix VI for explanation.

3.2 Species accumulation curves for each study site

A total of 56 species of birds were seen in all the urban and woodland sites during the year of the study (2001-2), see Appendix VI. Seven of these were introduced species (six non-native and the laughing kookaburra, a native Australian species introduced to Tasmania) and eleven were summer migrants. There were also several species which are thought to be local altitudinal migrants (Pizzey, 1997). Therefore, it was not expected that all birds were equally likely to be seen at all sites at all times, but that over the course of the study most of the birds present at a site should have been seen. The following species accumulation curves (Figures 3.1-3.8) represent how the number of bird species seen at each study site have increased with the number of visits.

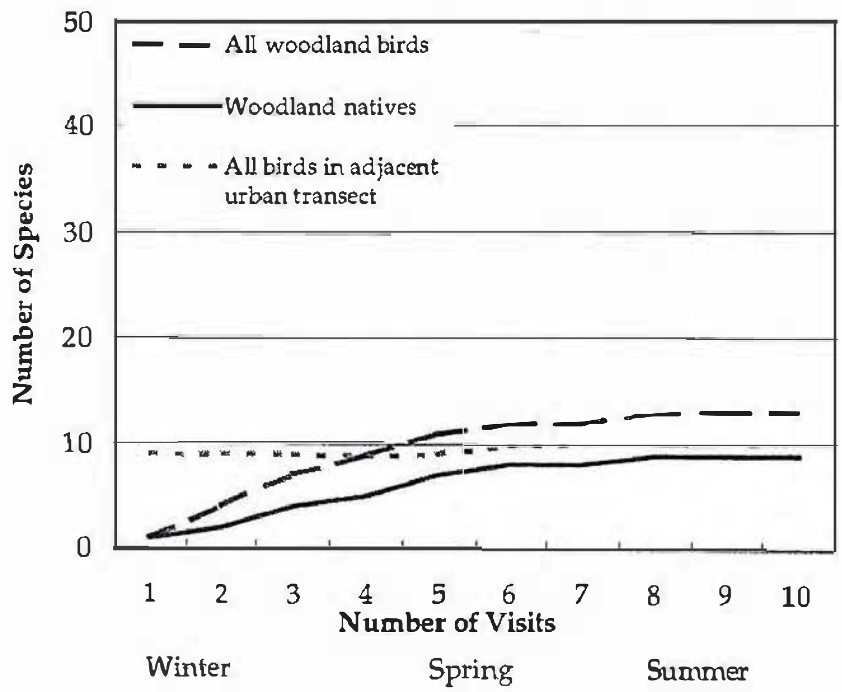

Figure 3.1 Species accumulation curves for Warrane

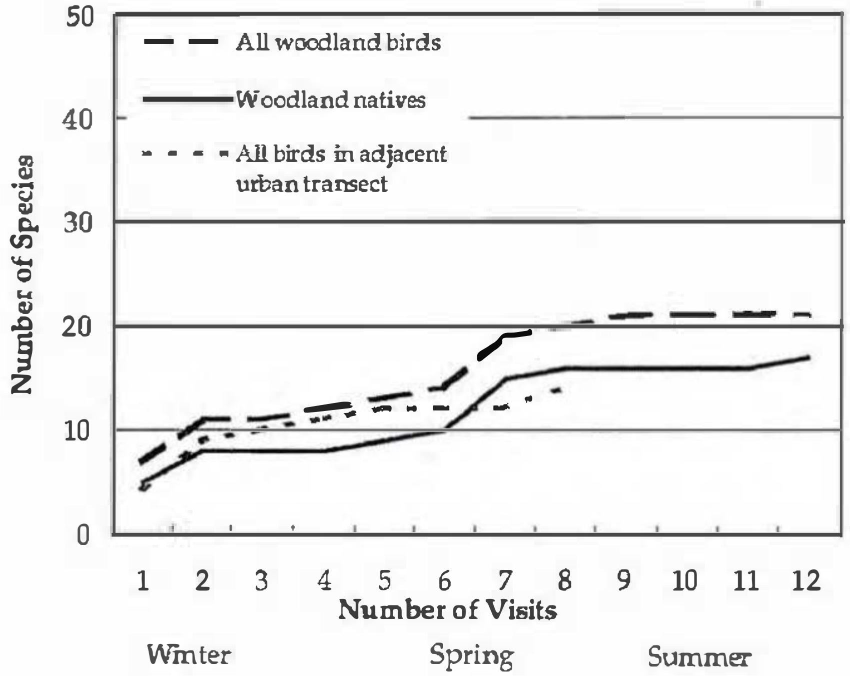

Figure 3.2 Species accumulation curves for Rosny

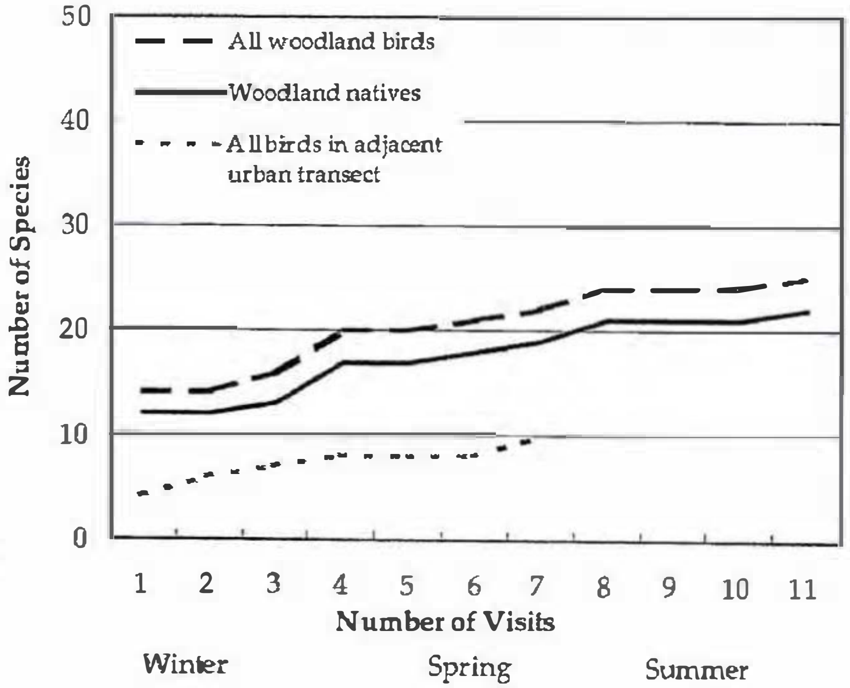

Figure 3.3 Species accumulation curves for Natone

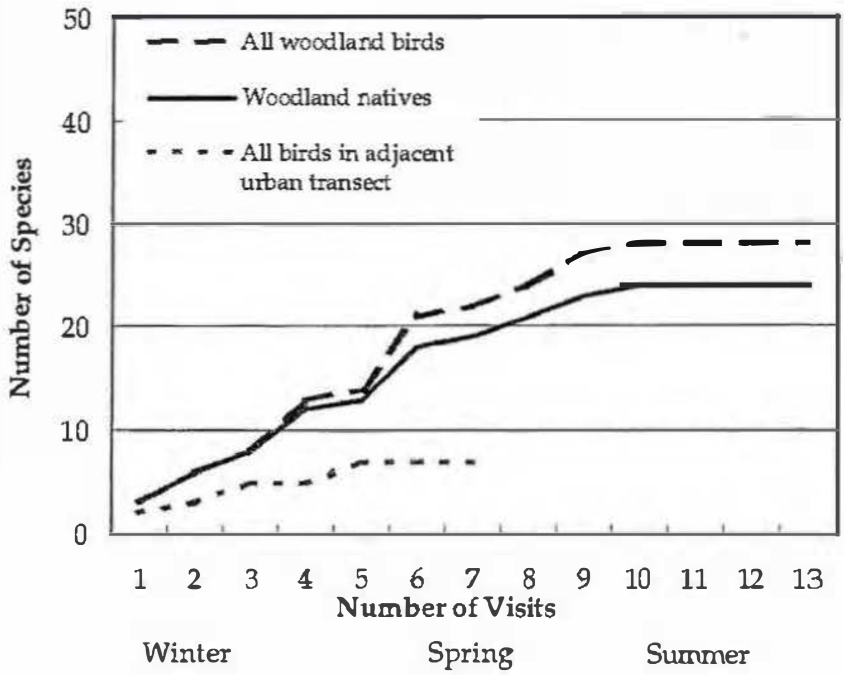

Figure 3.4 Species accumulation curves for Gordon

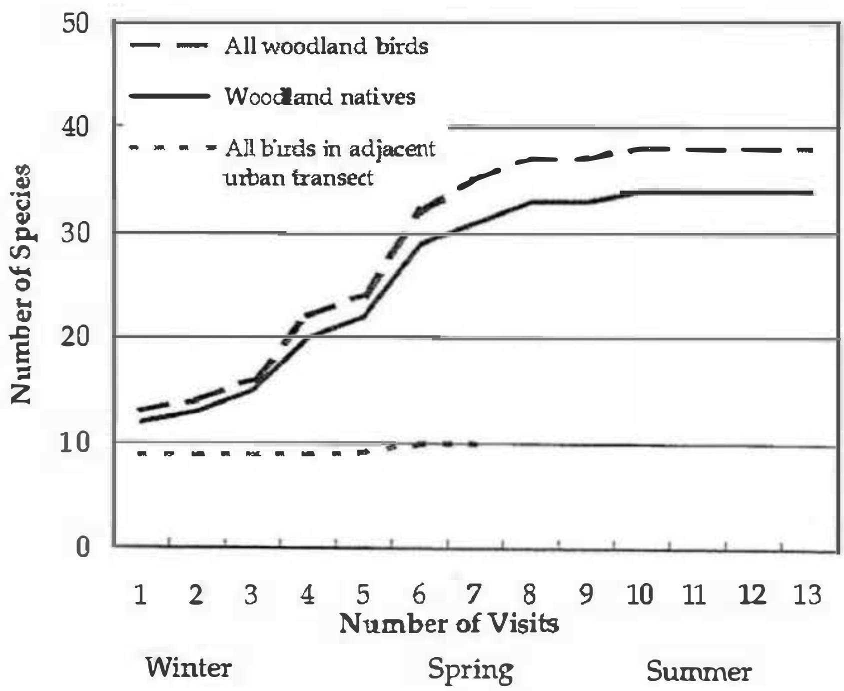

Figure 3.5 Species accumulation curves for Mornington

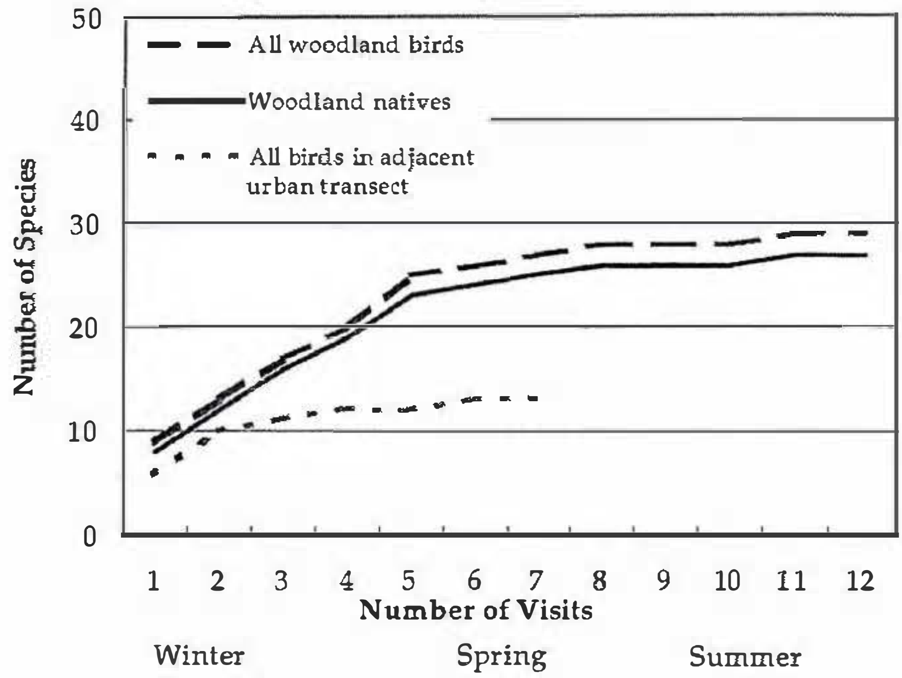

Figure 3.6 Species accumulation curve for Rokeby

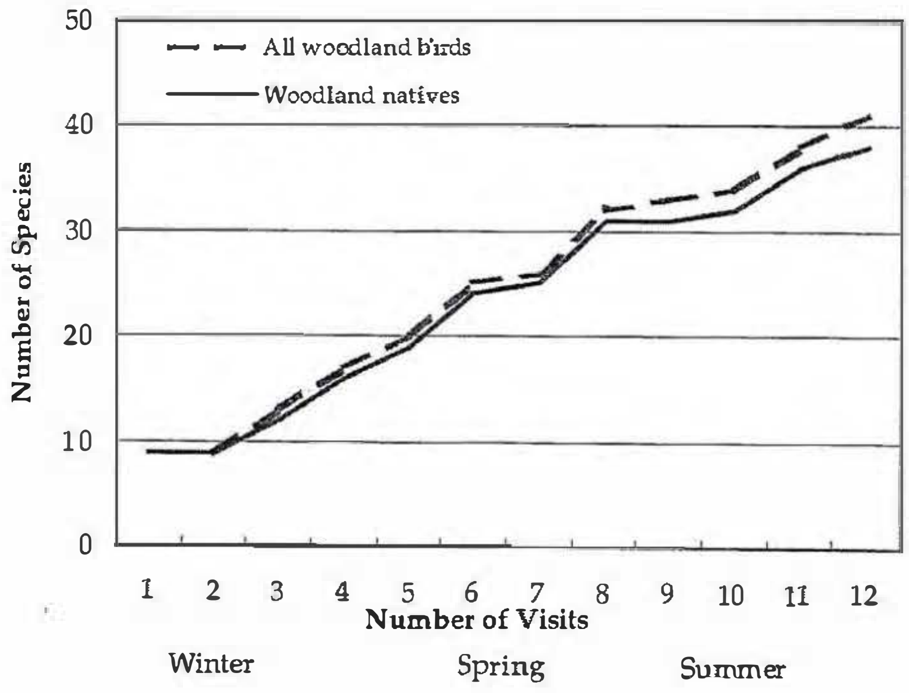

Figure 3.7 Species accumulation curves for Mount Rumney

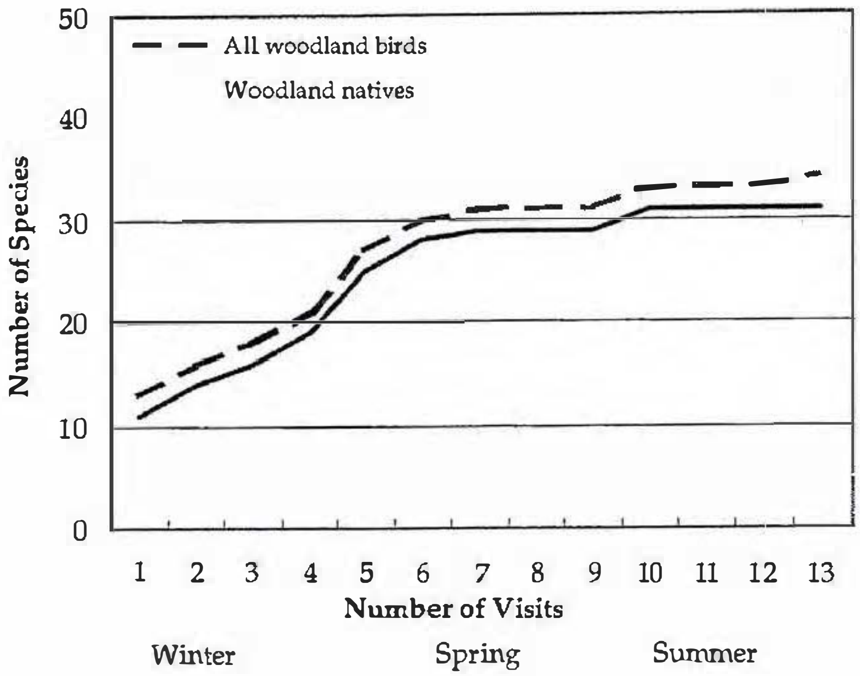

Figure 3.8 Species accumulation curves for Meehan

Figures 3.1 to 3.8 show the accumulation of bird species seen at each woodland and urban site as the visits progressed. These mostly show a plateau towards the end of winter and then a further rise through spring as the summer migrants were arriving, levelling out again at around eight to nine visits at the end of spring. Mount Rumney appears to be an exception to this with an almost linear rise from ten to forty species over the course of twelve visits. This was also the most diverse site in terms of bird species and the second largest in terms of area. This suggests that, because of the size of the larger sites and the limited coverage, there was insufficient effort, in terms of variety of transects and number of visits, to adequately predict the majority of species present in those areas (Mount Rumney and Meehan). However, as the gap in bird species diversity between the smaller and larger sites was only likely to get wider with more visits, it was considered acceptable to use the species data gathered to compare diversity with remnant woodland area (see chapters 3.5 and 4.5).

3.3 *Comparing urban and woodland bird species richness*

Comparing adjacent urban and woodland pairs of sites in terms of bird species richness (Figure 3.9) shows that woodland habitat always supports more species (13 to 38 species) than neighbouring urban habitat (7 to 14 species). There is also a general trend to more species in the larger woodland sites (in this case Rokeby is an exception). The woodland patch area increases from left to right on the x-axis in Figure 3.9. Paired t-tests show a highly significant difference between adjacent urban and woodland sites ($t_2 = -4.20$, $p < 0.001$) in terms of bird species richness.

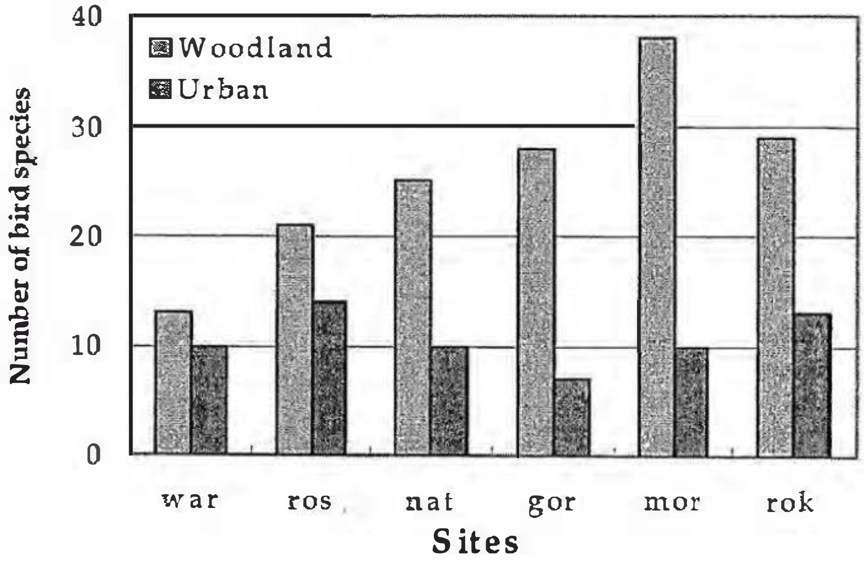

Figure 3.9 Histogram showing the overall bird species richness in adjacent urban and woodland sites. Sites are Warrane (war), Rosny (ros), Natone (nat), Gordon (gor), Mornington (mor) and Rokeby (rok).

3.4 *Comparing urban and woodland bird assemblages*

In order to investigate the bird assemblages in urban and woodland sites, the total native and introduced components of each of these two habitats were plotted by season in Figure 3.10. It shows that in the urban transects overall bird species diversity is made up of 31% (winter) to 36% (spring) introduced species, whereas in the woodland transects introduced species account for 14 to 15% of bird species. Paired t-tests comparing the averages of total bird species observed in transects between adjacent pairs of urban and woodland sites show highly significant differences: winter ($t_2 = -4.28$, $p = 0.0013$); spring ($t_2 = -4.51$, $p < 0.001$) and winter/spring ($t_2 = -5.85$, $p < 0.001$). However, there was no significant difference in the richness of bird species observed in transects at the same urban sites in winter and spring ($t_2 = 1.12$, $p = 0.147$), or in transects at the same woodland sites in winter and spring ($t_2 = -0.38$, $p = 0.356$).

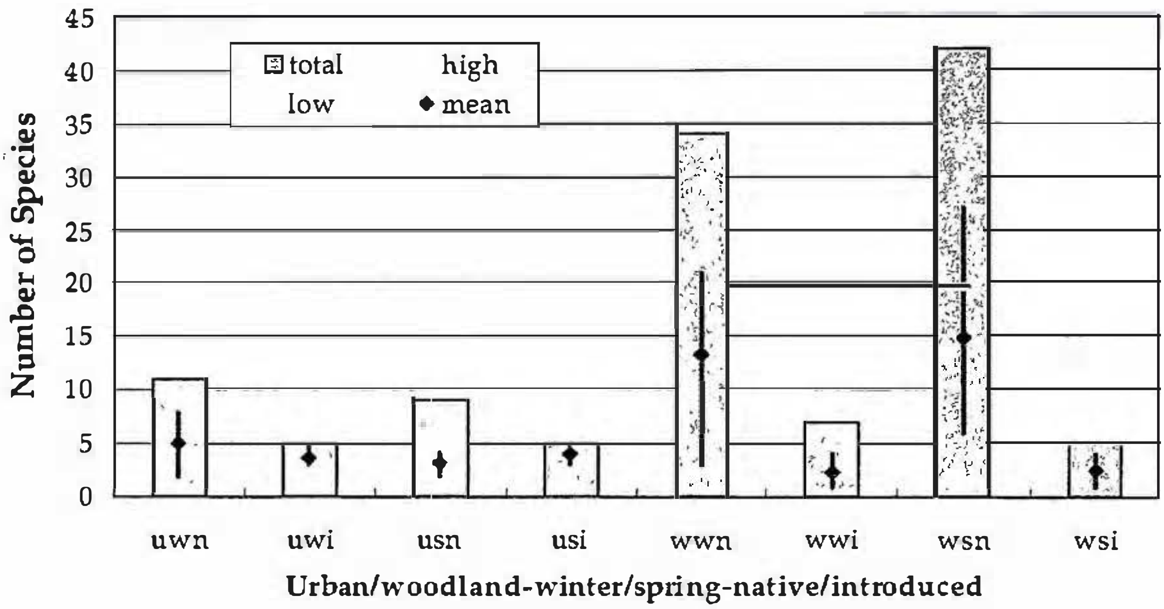

Figure 3.10 Histogram of bird species richness comparing the number of native and introduced bird species recorded in the urban and woodland pairs of sites by season. (Codes are: uwn = urban-winter-native; uwi = urban-winter-introduced; usn = urban-spring-native; usi = urban-spring-introduced; wwn = woodland-winter-native; wwi = woodland-winter-introduced; wsn = woodland-spring-native; wsi = woodland-spring-introduced)

Since there were no significant differences between the seasons the data were pooled for further comparison. The urban sites were compared with their respective adjacent woodland sites using paired t-tests in terms of the numbers of native and introduced birds. This showed highly significant differences for native birds between urban and woodland pairs ($t_2 = -3.46$, $p = 0.003$) and for introduced birds between urban and woodland pairs ($t_2 = 5.95$, $p < 0.001$), see also Figure 3.11; and also significant differences in total numbers of birds, see Figure 3.12. Note that in order to compare these figures accurately in terms of effort (length and width of transect, and number of visits), the only data used were those which were gathered on days where both the urban and woodland sites in an adjacent pair were visited. Further for this test, only those records of birds observed within thirty metres of the transect line were used, to account for the restriction imposed on the urban transects by the buildings along each side of the street. Also, as there were twice as many woodland transects as urban transects, the woodland figures were reduced by half. Figure 3.11 then shows the relative proportion of the number of individuals of native and introduced birds at each pair of urban and woodland sites.

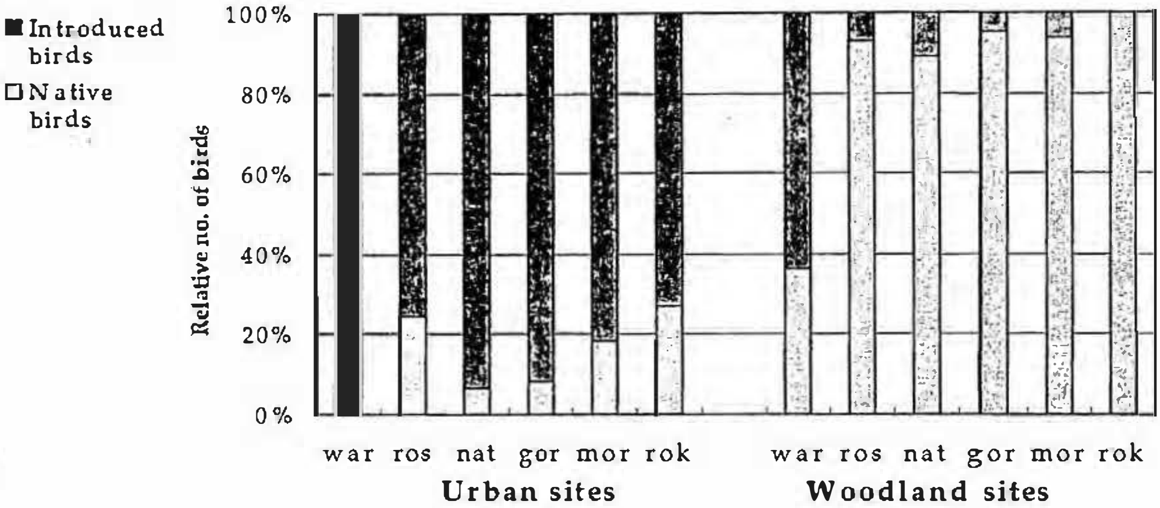

Figure 3.11 Histogram of relative numbers of native and introduced birds at each pair of urban and woodland sites.

The bird population was composed of 6 to 27 percent native species in urban sites, but 89 to 100 percent natives in the adjacent woodland sites, with overall little seasonal variation (Figure 3.12). The most frequently counted species in the urban environment were the common starling (38%), house sparrow (30%), blackbird (8%) and the little wattlebird (6%), with two introduced species (greenfinch and laughing kookaburra) not observed. In the woodlands the most frequently counted species were the brown thornbill (14%), silvereye (14%), yellow-throated honeyeater (11%) and black-headed honeyeater (8%), but the most frequently observed introduced species (blackbird and goldfinch) only represented 1.5% of the population each.

Figure 3.12 shows the data for the six pairs of urban and woodland sites collated for the winter and spring seasons. The only apparent change is that the relative number of native birds doubles in the winter in the urban areas possibly because some species like the silvereye become nomadic and some altitudinal migrants wander to lower areas in winter in search of food (for example, the crescent honeyeater which visits gardens for fruit and flowers).

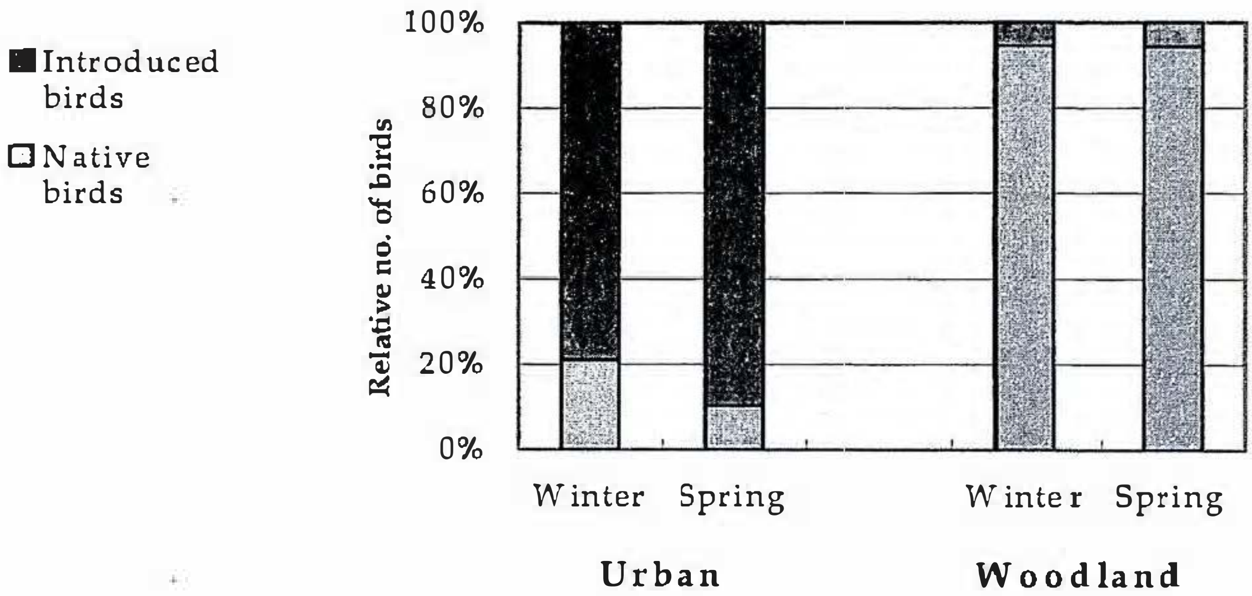

Figure 3.12 Histogram of overall relative numbers of native and introduced birds by season at urban and woodland sites.

Figure 3.13, produced using the software PATN (Belbin, 1993), shows the relationship between the various sites based on the numbers of individuals of all species recorded by season during the urban and woodland transects. Sites connected together nearer the left are most similar, dissimilarity increasing to the right. For example, the urban group of sites (pink) are most unlike all woodland sites. More similar, but generally in distinct groups are the large (green) and medium (blue) woodland remnants. The small woodland site of Warrane (red) appears as an intermediate step between the woodland and urban habitats. There is also some clumping by season.

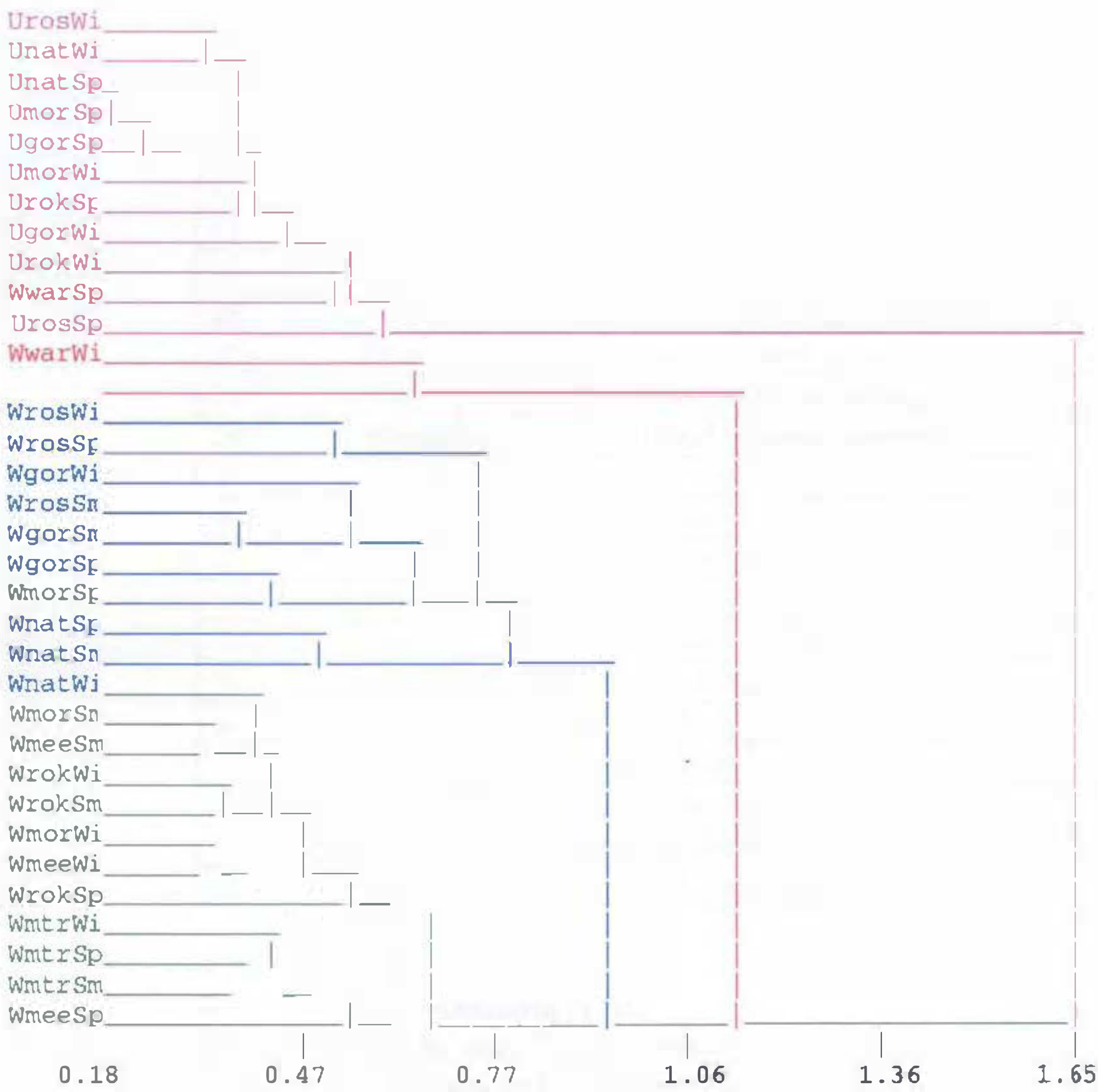

Figure 3.13 UPGMA dendrogram showing relationship of all the woodland and urban sites based on the abundance of the different bird species recorded at each site. Transect colour code: pink - urban, red - small woodland, blue - medium woodland, green - large woodland.

Table 3.1 Order of sites in TWINSPAN Figure 3.15 (see top x-axis)

Site no.	Site code	habitat-Site-season
16	WrokWi	woodland Rokeby winter
24	WrokSp	woodland Rokeby spring
32	WrokSm	woodland Rokeby summer
17	WmtrWi	woodland Mt Rumney winter
25	WmtrSp	woodland Mt Rumney spring
26	WmeeSp	woodland Meehan spring
33	WmtrSm	woodland Mt Rumney summer
15	WmorWi	woodland Mornington winter
18	WmeeWi	woodland Meehan winter
34	WmeeSm	woodland Meehan summer
22	WgorSp	woodland Gordon spring
23	WmorSp	woodland Mornington spring
13	WnatWi	woodland Natone winter
14	WgorWi	woodland Gordon winter
30	WgorSm	woodland Gordon summer
31	WmorSm	woodland Mornington summer
11	WwarWi	woodland Warrane winter
12	WrosWi	woodland Rosny winter
27	WwarSm	woodland Warrane summer
28	WrosSm	woodland Rosny summer
20	WrosSp	woodland Rosny spring
21	WnatSp	woodland Natone spring
29	WnatSm	woodland Natone summer
6	UrosSp	urban Rosny spring
7	UnatSp	urban Natone spring
8	UgorSp	urban Gordon spring
19	WwarSp	woodland Warrane spring
2	UnatWi	urban Natone winter
3	UgorWi	urban Gordon winter
9	UmorSp	urban Mornington spring
1	UrosWi	urban Rosny winter
4	UmorWi	urban Mornington winter
5	UrokWi	urban Rokeby winter
10	UrokSp	urban Rokeby spring

Pink = urban
Red = small woodland (1 ha)
Blue = medium woodland (15-60 ha)
Green = large woodland (over 80 ha)
Category according to Dendrogram (Figure 3.13) and area.

For each site at each season the numbers of birds were totalled for all the surveys. These sites were ordinated using semi-strong hybrid multi-dimensional scaling (SSH MDS) according to their bird assemblages, using the computer program PATN (Belbin, 1993), Figure 3.14 is the resulting plot.

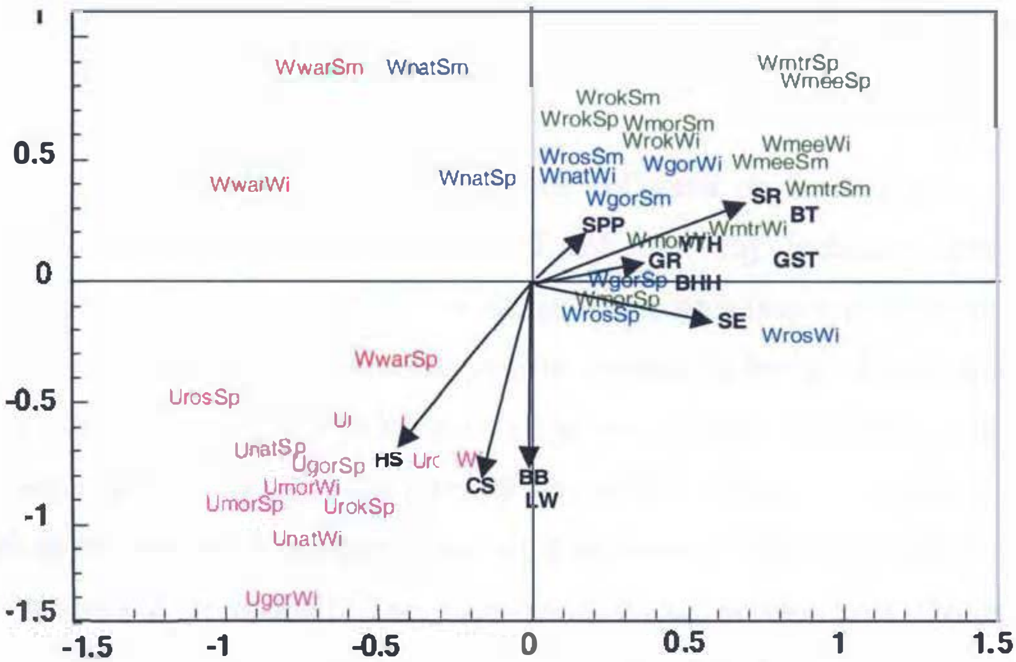

Figure 3.14 Ordination (SSH MDS) of the woodland and urban sites, showing the bird species which were significant predictors (see Table 3.2) of the variation between the sites fitted as vectors (see Table 3.1 for site codes and Table 3.3 for bird codes).

The ordination plot (Figure 3.14) highlights which bird species are most significant in determining the relative positions of the plotted sites and hence their similarity or otherwise. To be significant in the placement of sites within the ordination, a species must be a common bird rather than rare and located in a few sites rather than across all sites. The three very common introduced species (house sparrow, common starling and blackbird) and one native (little wattlebird) are most significant in defining the urban cluster, while eight of the more common native species are most significant in defining the woodland cluster. These are: brown thornbill, silvereye, yellow-throated honeyeater, black-headed honeyeater, spotted pardalote, green rosella, grey shrike-thrush, and the scarlet robin (see Table 3.2). The ordination also demonstrates the clustering of sites into urban and woodland groups. The sub-grouping of woodland sites implies size of remnant increasing from left to right on the 'x' axis and increasing effect of urbanisation from top to bottom on the 'y' axis.

Table 3.2 Bird species correlation values (>0.6) with the ordination from a Monte Carlo test. (All birds shown are more than 98% significant).

CS	0.862	HS	0.783	BB	0.706	LW	0.682
YTH	0.889	SPP	0.866	BT	0.760	BHH	0.739
SR	0.729	GR	0.716	GST	0.712	SE	0.616

See Table 3.3 for full names of bird species.

PATN (Belbin, 1993) also allows for the data collected on bird species and abundance to be displayed in a TWINSPAN (two-way indicator species analysis) classification (Figure 3.15). This classifies the sites (top x-axis) in terms of their bird assemblages; and the bird species (y-axis) in terms of the sites at which they were recorded. The bottom x-axis shows the sites split into groups, the first major split being between sites 29 and 6 (this relates to the urban to woodland split); the next most significant split is between sites 34 and 22 (large to small woodland remnants). The right-hand y-axis shows how the bird species have been split into groups according to the sites they were recorded in. Again the first major split is between the silvereye (SE) and the yellow wattlebird (YW) which signifies the groups of birds broadly preferring the woodland or urban ends of the habitat spectrum. The next most significant splits, between the greenfinch (GRF) and eastern rosella (ER) and also between the goldfinch (GOF) and crescent honeyeater (CH), highlight a group of birds of a more generalist nature (ER to GOF), below which are the urban specialists and above which are the woodland specialists. The species nearer the top of the list generally can be said to be more dependant on large woodland remnants and those nearer the bottom are the most urban tolerant species. There is also a less significant split between the striated pardalote (STP) and the superb fairy-wren (SFW) which effectively divides the woodland group of birds into those that prefer the larger remnants, strong-billed honeyeater (SBH) to striated pardalote (STP), and those which appear to be general woodland birds, superb fairy-wren (SFW) to greenfinch (GRF).

```
           Site 1231223311 3221133112222    1       | 1
Bird       Code 6427563584 2334011278019 678923910 |50
code
16 IM           453------- ------------- --------- 42   000
18 SBH          ---23---13 --1---------- --------- --   001000
23 FRO          -----32--- ------------- --------- --   001000
25 DR           ---2212-23 ------------- --------- --   001000
39 EG           ------1--- ------------- --------- --   001000
40 WBSE         ----1----- ------------- --------- --   001000
43 BF           ---1112--- ------------- --------- --   001000
45 CBW          -----1---- ------------- --------- --   001000
46 BBW          -------1-- ------------- --------- --   001000
48 SCC          ---32-2--- ------------- --------- --   001000
 2 GR           4225534342 -2----------1 --------- --   001001
22 ES           --------21 1--1--------- --------- --   001001
42 SH           -2-------- ------------- --------- --   001001
 4 BWP          ----434--- -3---1------- --------- --   001010
 5 PC           -1--22---- -2----------- --------- --   001010
 6 FTC          -312341-22 ----22---1--- --------- --   001010
 8 SBC          ----22---- 1------------ --------- --   001010
19 BHH          4135445554 -32--4------- --------- --   001010
27 GW           1--213-133 --21-1------- --------- --   001010
28 GST          22-2344231 21-12-------- --------- --   001010
37 TM           -5--542-2- ----------222 --------- --   001010
10 SPP          4445534444 -3413422----2 ---1----- --   001011
11 STP          -13-555122 45---2------- --------- --   001011
________________________________________________________________
 9 SFW          ---1242333 -41--3-----1- ---2----- --   001100
 7 HBC          ----11---- -2----------- --------- --   001101
12 BT           5544352555 4545352412232 --------- --   001101
17 YTH          5545545455 334234-212122 --------1 --   001101
24 SR           3332-23343 223323------- --------- --   001101
26 OW           11---12311 ---321-2----1 --------- --   001101
35 FRA          2424423322 2332-2-3-1443 --------- --   001101
50 LK           ----11--22 22--11------- --------- --   001101
 1 ML           2-2------- -2---2------- --------- --   001110
29 GF           --2--233-3 251113-2-21-- --------- --   001110
30 BFC          -43--12--2 441-1------4- 1-------- --   001110
44 AH           -------1-- -1-1------1-- --------- --   001110
13 YRT          --2------- -122--------- --------- --   001111
31 DWS          -1---2---3 34---------1- --------- --   001111
41 WTE          ---------- -1---1------- --------- --   001111
47 YBC          ---------- -----------2- --------- --   001111
52 GRF          ---------- --------3---- --------- --   001111
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 3 ER           22--2----- -2----------- --------- 21   01
32 GB           122---1--- --1--2-1-1132 ---11-11- --   01
34 GC           13---3-123 211-21---2231 --------1 4-   01
38 SE           --2--332-4 453545-524532 -123---3- --   01
________________________________________________________________
15 YW           13211----2 2-2-111-11243 22-11-211 1-   10
36 WS           ---------- ------------2 --------- -1   10
51 GOF          12----111- 1222422313-2- 2142----- 24   10
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
21 CH           ---2--111- -------2----- ----1--22 --   110
54 BB           -1-----3-3 431-11-2--331 323322244 33   110
14 LW           -------1-- 2--1------2-- 1-2123342 31   11100
20 NHH          ---------- ------------- -----2-22 2-   11100
53 HS           ---2------ ------1------ 555245544 34   11100
55 CS           ---------- -3----22----- 355455554 55   11100
33 AM           2--------- ------------- 1------2- --   11101
49 STD          ---------- --2---------- --------2 42   1111

                0000000000 0000000000000 111111111 11
                0000000000 1111111111111 000000000 11
                0001111111 0000001111111 000011111
                   0000111 0011110000111     00011
```

Figure 3.15 TWINSPAN analysis showing the classification of sites based on the bird species found at each site (x-axis) and the classification of bird species based on the sites where they are found (y-axis), see Tables 3.1 and 3.3 for site and bird codes. The lines signify the most significant splits.

Table 3.3 Order of Species in TWINSPAN (Figure 3.15) and species codes.

16	NM	Noisy miner
18	SBH	Strong-billed honeyeater
23	FRO	Flame robin
25	DR	Dusky robin
39	BG	Brown goshawk
40	WBSE	White-breasted sea-eagle
43	BF	Brown falcon
45	CBW	Common bronzewing
46	BBW	Brush bronzewing
48	SCC	Sulphur-crested cockatoo
2	GR	Green rosella
22	ES	Eastern spinebill
42	SH	Swamp harrier
4	BWP	Blue-winged parrot
5	PC	Pallid cuckoo
6	FTC	Fan-tailed cuckoo
8	SBC	Shining bronze-cuckoo
19	BHH	Black-headed honeyeater
27	GW	Golden whistler
28	GST	Grey shrike-thrush
37	TM	Tree martin
10	SPP	Spotted pardalote
11	STP	Striated pardalote
9	SFW	Superb fairywren
7	HBC	Horsfield's bronze-cuckoo
12	BT	Brown thornbill
17	YTH	Yellow-throated honeyeater
24	SR	Scarlet robin
26	OW	Olive whistler
35	FRA	Forest raven
50	LK	Laughing kookaburra
1	ML	Musk lorikeet
29	GF	Grey fantail
30	BFC	Black-faced cuckoo-shrike
44	AH	Australian hobby
13	YRT	Yellow-rumped thornbill
31	DWS	Dusky woodswallow
41	WTE	Wedge-tailed eagle
47	YBC	Yellow-tailed black cockatoo
52	GRF	Greenfinch
3	ER	Eastern rosella
32	GB	Grey butcherbird
34	GC	Grey currawong
38	SE	Silvereye
15	YW	Yellow wattlebird
36	WS	Welcome swallow
51	GOF	Goldfinch
21	CH	Crescent honeyeater
54	BB	Blackbird
14	LW	Little wattlebird
20	NHH	New Holland honeyeater
53	HS	House sparrow
55	CS	Common starling
33	AM	Australian magpie
49	STD	Spotted turtle dove

3.5 Comparing species richness with area of habitat

Figure 3.16 shows the number of native and the total number of bird species found at each woodland site related to the logarithm of the site area. The peaks at about 80 and 800 hectares are Mornington and Mount Rumney; the dips at 160 and 3,100 hectares are Rokeby and Meehan. Since the latter two sites have a high proportion of *Eucalyptus risdonii,* which may account for their relatively depauperate nature (see Chapter 4.5), removing them gives the species-area relationship shown in Figure 3.17. In both cases there is a step change of approximately 10 to 15 species at about 80 hectares.

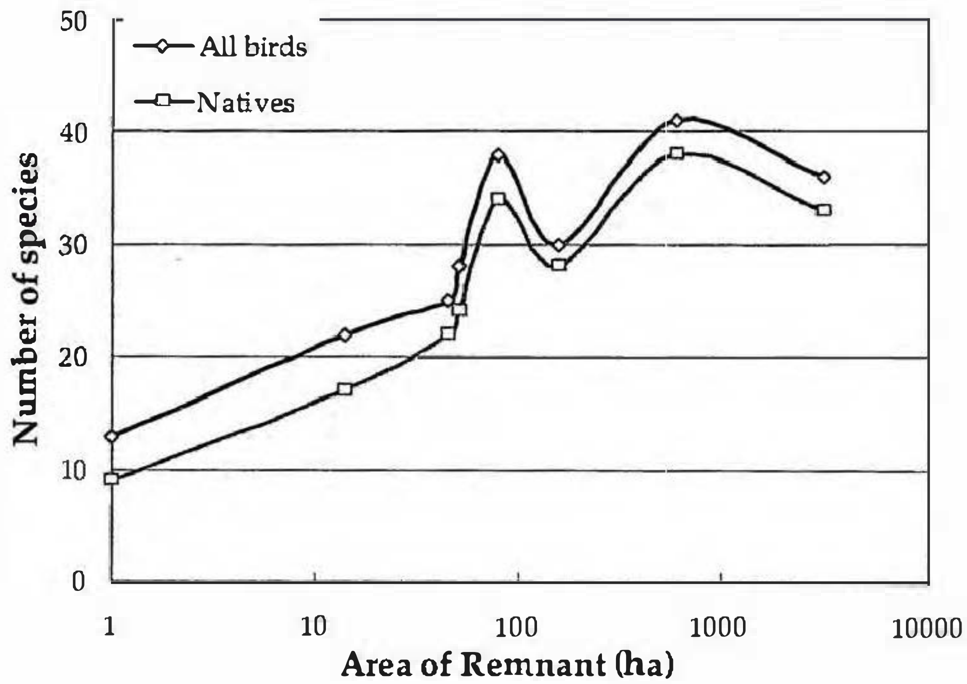

Figure 3.16 Bird species richness against woodland remnant area

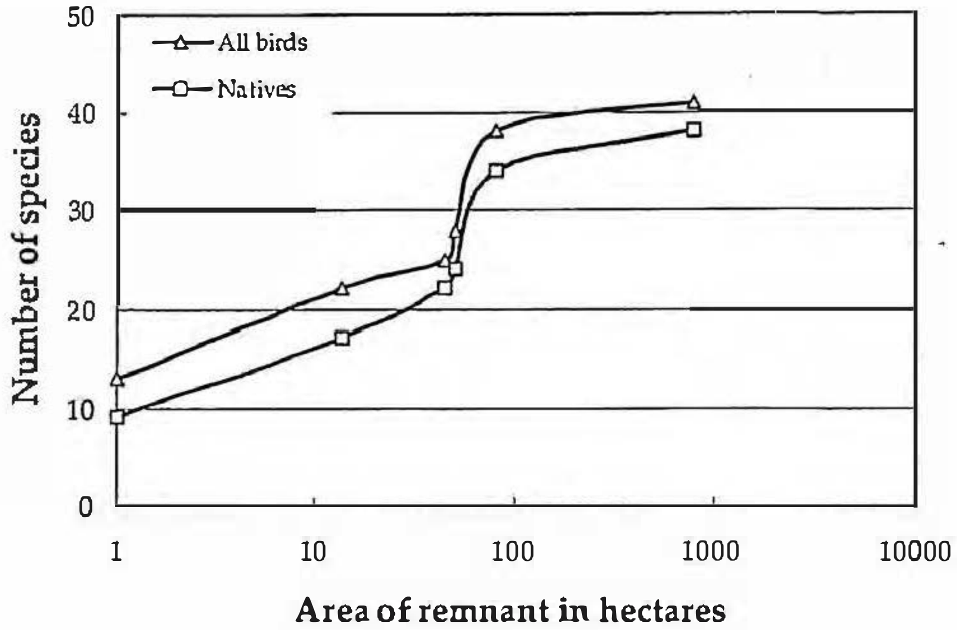

Figure 3.17 Bird species richness against woodland remnant area with Rokeby and Meehan removed.

In Figure 3.18 equations and r^2 values for power trendlines are fitted to the bird species-area graph. The high r^2 values show it is likely that remnant area is a strong influence on bird species variety in this study.

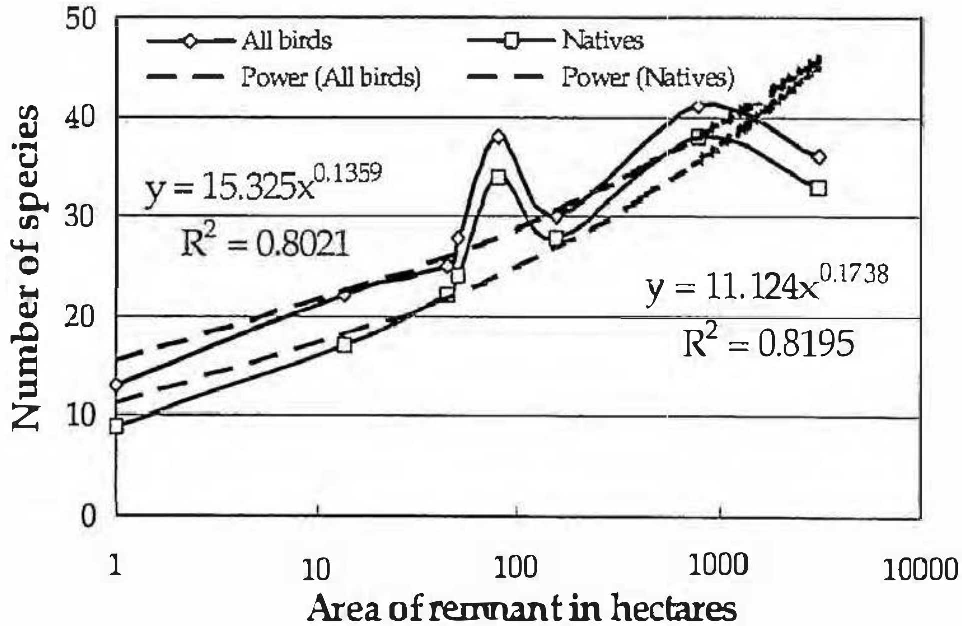

Figure 3.18 Power trendlines fitted to species/area graph.

3.6 Bird density estimates using DISTANCE

DISTANCE was run first to obtain a range of densities of all native birds over a range of different truncation distances to determine at what level of truncation of the observations the most stable estimate of density was found. Table 3.4 shows that the overall native bird density varied with truncation at each site, but was most stable around the mid-distance of the original transect width (25-28 metres). Therefore, for the more commonly observed species a truncation distance of 26 metres was chosen. However, this occasionally gave unreasonable results where the probability of detecting a particular species was nearer to 1.0 (that is always observed where present) and a high percentage of its observations were distant (nearer to 50 metres). In these cases no truncation distance was set and all observations were included to increase precision. The observation of 125 silvereyes at Rosny was removed from the data set on the grounds that this was a highly irregular occurrence of nomadic birds which flew in from outside the area and departed soon after. This spike in the data causes an increase of about 2 birds per hectare in the density of birds at Rosny over the whole study period.

Table 3.4 Native bird density (birds per hectare) at each woodland site at different truncations of observations.

Truncation (m):	50	45	38	35	31	30	28	26	25	16	11	Mean
Site												
Warrane	4.0	6.4	7.1	7.5	6.3	6.5	6.7	6.8	6.8	8.7	8.2	6.8
Rosny*	6.4	6.1	6.6	6.5	8.0	8.1	8.2	8.3	8.3	7.8	7.9	7.4
Natone	6.3	5.7	6.0	7.1	7.2	7.1	6.6	6.3	6.1	6.9	6.9	6.6
Gordon	8.8	10.9	12.0	11.9	11.0	10.8	11.7	12.1	12.0	11.3	9.9	11.1
Mornington	14.6	21.3	21.3	21.0	19.7	19.4	21.7	21.7	21.4	31.4	28.3	22.0
Rokeby	7.6	8.7	11.7	13.5	10.2	7.1	13.7	12.9	12.6	18.6	10.9	11.6
MtRumney	12.7	23.0	24.2	23.7	18.1	17.5	23.9	22.0	21.5	37.4	30.8	23.2
Meehan	9.4	13.1	13.6	13.4	11.6	11.2	13.4	13.2	12.7	12.4	12.2	12.4
No. sites within												
5% of mean	1	2	4	2	3	3	5	4	4	4	2	

Bold figures represent densities within 5% of the mean.
* Bird density at Rosny with one observation of 125 silvereyes removed.

By estimating the overall native bird density at each site it was then possible to determine if there were any change in density with area, since reduction in both species richness and density affect diversity. Using the overall native bird density estimates for each site calculated by DISTANCE with observations truncated beyond 26 metres, gives the following relationship plotted against the woodland remnant area.

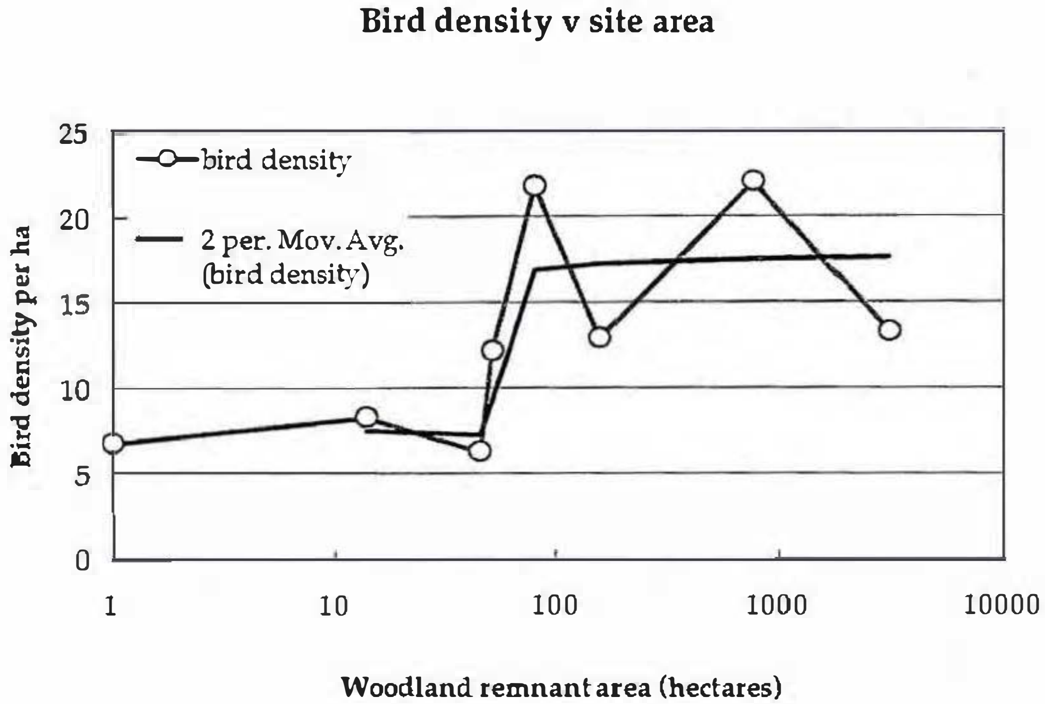

Figure 3.19 Native bird species density with woodland remnant area. '2 per moving average' means the average of each adjacent pair of points on the graph.

Figure 3.19 shows a similar reduction in density of birds with reducing area at each site as Figure 3.16 shows a reduction in species richness with reducing area. These effects compound to reduce the bird diversity in the smaller remnants.

3.7 Bird population estimates at each site

Table 3.5 lists the individual bird species densities as estimated by DISTANCE. It shows that the bird species able to utilise the smaller remnants are generally also found in the larger remnants (for example: yellow-throated honeyeater YTH, brown thornbill BT, spotted pardalote SPP, silvereye SE, forest raven FRA, grey fantail GF and yellow wattlebird YW), but that some species found in the larger remnants are often not found in the smaller remnants (for example: striated pardalote STP, green rosella GR, grey shrike-thrush GST, fan-tailed cuckoo FTC, blue-winged parrot BWP and dusky robin DR).

Table 3.5. Individual species density at each woodland site (birds per ha) of the 23 birds most frequently observed in this study. Note that where the total number of observations for a species at a site is less than approximately 30, the 95% confidence level of the density estimate is wide, but still gives an indication of the population density. The average is weighted by area of remnant.

SPECIES	Total Observations	Warrane	Rosny	Natone	Gordon	Mornington	Rokeby	MtRumney	Meehan	Weighted average
YTH	284	0.09	0.59	0.35	0.45	1.21	2.26	3.99	0.59	1.28
BT	210	1.44	0.58	1.05	2.86	4.42	2.42	1.25	2.41	2.21
SPP	152	2.78	0.03	0.43	0.1	0.52	0.81	2.09	0.5	0.8
SE	134	0.61	5.8	0.97	4.71	3.16	0.16	0.14	0.82	0.78
STP	126	0	0	0	0.94	0.77	0.08	1.74	1.07	1.14
BHH	102	0	0	0.06	0	1.15	0.93	3.73	2.51	2.59
FRA	93	0	0.26	0.59	0.17	0.21	0.29	0.5	0.1	0.19
SR	71	0	0	0.27	0.37	0.48	0.28	0.5	0.39	0.4
GF	60	0	0.11	0.02	0.11	0.94	0.05	0.18	0.36	0.32
GR	59	0	0	0.02	0	0.19	0.21	0.76	0.18	0.29
GST	56	0	0	0	0.08	0.27	0.07	0.28	0.2	0.1
BFCS	55	0	0	0.75	0.29	0.45	0.48	0.06	0.04	0.08
FTC	43	0	0	0	0.05	0.36	0.1	0.13	0.2	0.08
GC	35	0	0	0.17	0.05	0.04	0.19	0	0.11	0.09
YW	34	0.04	0.04	0.67	0.22	0.01	0.15	0.03	0.04	0.09
SFW	26	0.18	0	0.12	0	2.18	0	0.01	0.59	0.48
GW	26	0	0	0.03	0.01	0.03	0.01	0.06	0.15	0.05
OW	25	0	0	0.02	0.22	0.13	0.03	0.06	0.08	0.05
GB	23	0	0	0.14	0	0.04	0.08	0.01	0	0.04
BWP	23	0	0	0	0	0.28	0	0.42	0.16	0.2
DWS	20	0	0	0.02	0.14	0.49	0.01	0	0.04	0.04
TM	19	0	0.04	0.09	0	0	0.27	0.64	0.87	0.76
DR	13	0	0	0	0	0	0	0.24	0.7	0.56

No adjustments of effort were made for the migratory species (striated pardalote STP, black-faced cuckoo -shrike BFCS, fan-tailed cuckoo FTC, blue-winged parrot BWP, dusky woodswallow DWS and tree martin TM), therefore, their densities while present are higher than shown. Also estimations of density could not be reasonably calculated for infrequently observed birds.

From the density figures for each site (shown for the more frequently observed birds in Table 3.5), estimates of bird species populations across each site were calculated by DISTANCE and then grouped in the following categories: zero, present, 1 - 9, 10 - 49, 50 - 499, >500 and shown in Figure 3.20 (see Discussion 4.7).

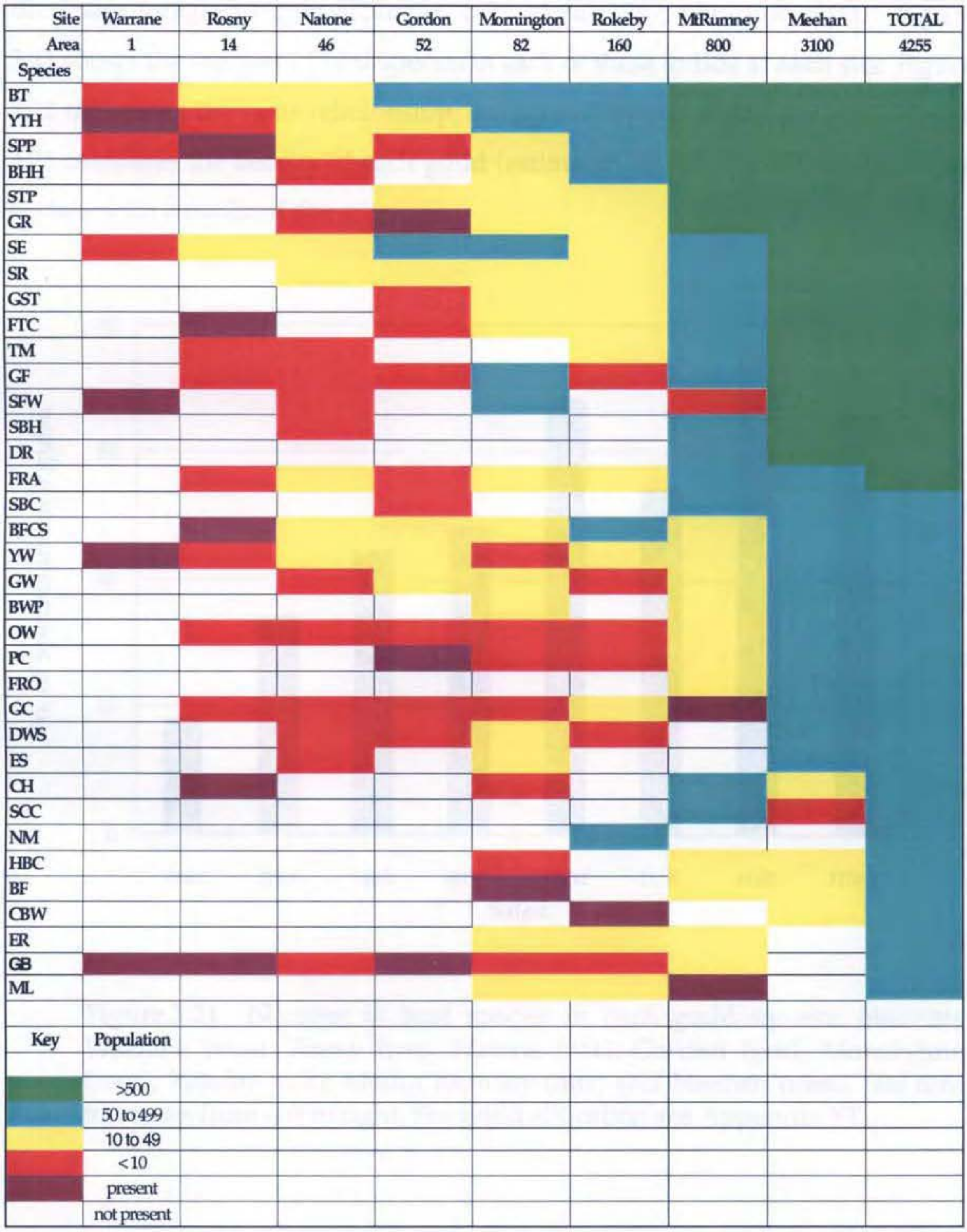

Figure 3.20 Estimated bird populations at each site

3.8 Partitioning of birds at each site

In order to attempt to explain why there are gaps in the population chart (Figure 3.20) where certain species might reasonably be expected to occur, for example the superb fairy-wren (SFW) at Rokeby, the birds were partitioned into four guilds: ground, shrub, tree and air (see Appendix VI). This was a simplification of the partitioning of the woodland bird assemblage based on the dominant foraging height (Thomas, 1979; Ford, 1989; Hingston, 2000). Figure 3.21 shows the number of bird species in each of these guilds at each site. Figure 3.22 represents the same relationship, but plotted by woodland site area. Figure 3.23 compares the density of each guild (estimated by DISTANCE) in birds per hectare with woodland site area.

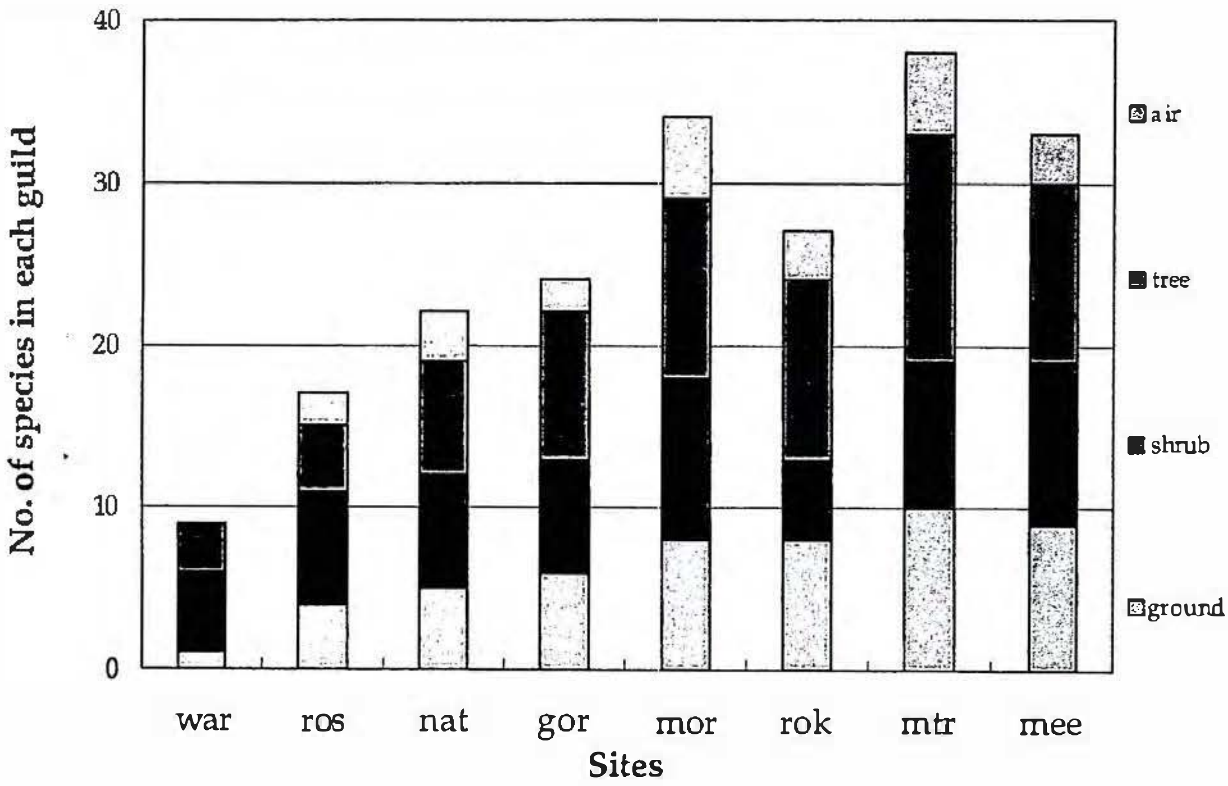

Figure 3.21 Number of bird species in each guild by site. Sites are Warrane (war), Rosny (ros), Natone (nat), Gordon (gor), Mornington (mor), Rokeby (rok), Mount Rumney (mtr) and Meehan (mee). Site area increases from left to right. For guild allocation see Appendix VI.

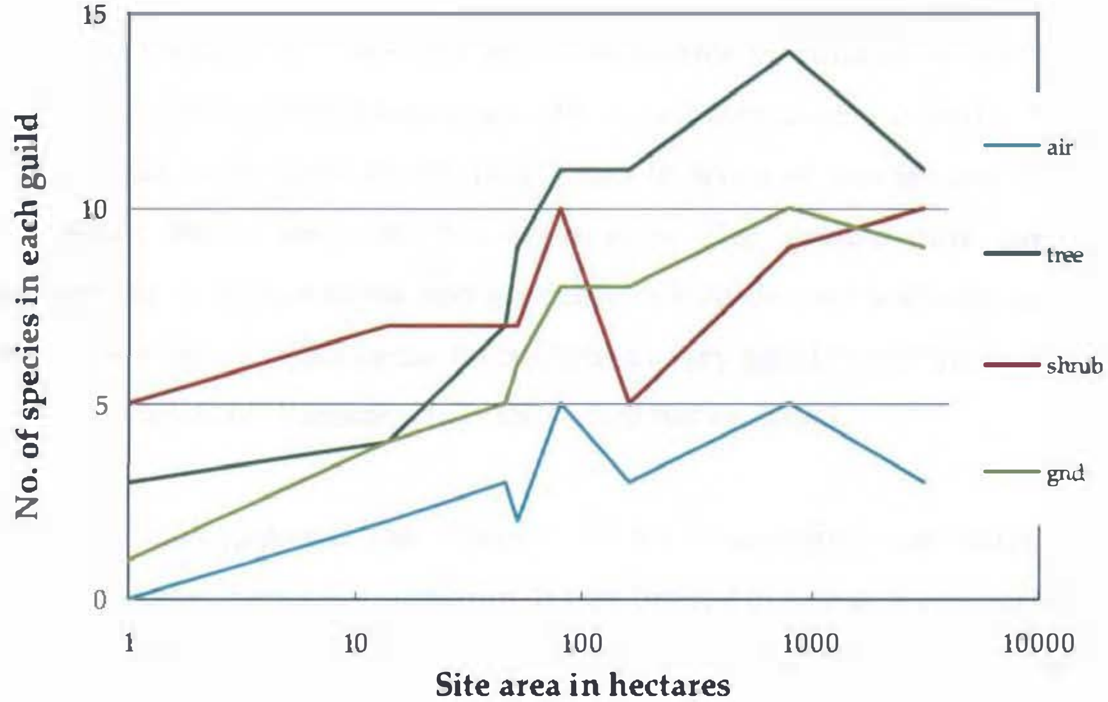

Figure 3.22 Number of bird species in each guild by site area

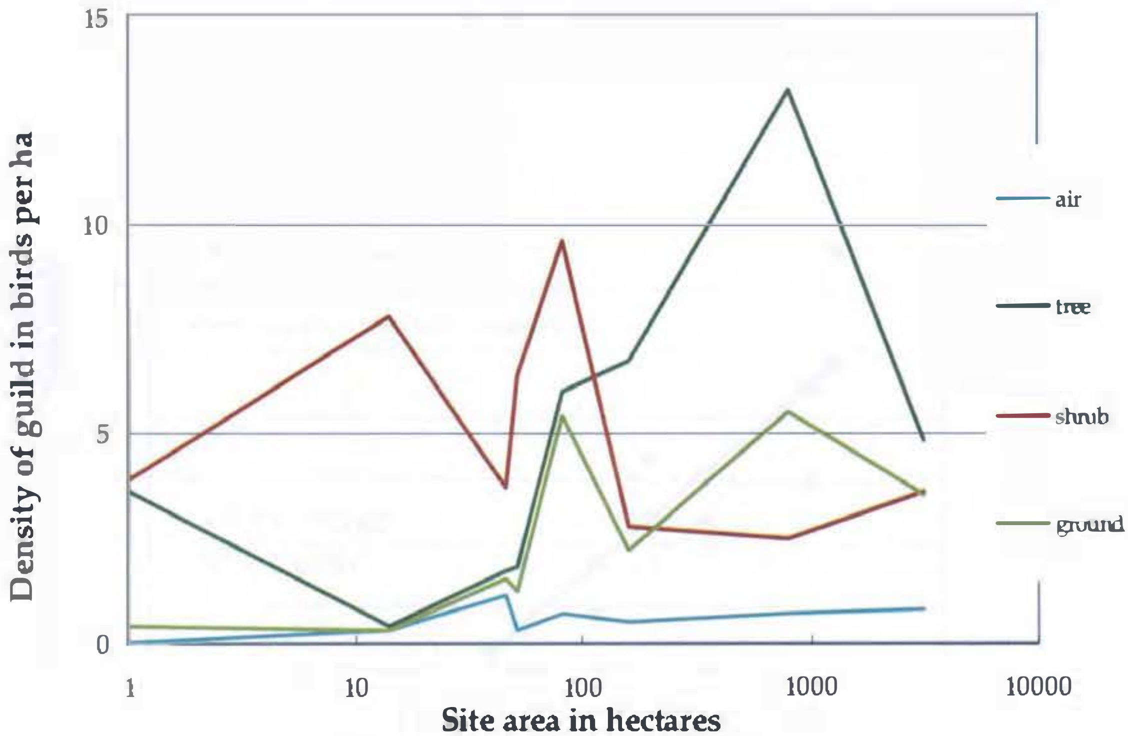

Figure 3.23 Density of birds in their respective guilds plotted against the site area in hectares.

Figures 3.22 - 3.23 show that, in this study, the 'shrub-bird' guild has the highest proportion of species and highest density in the smaller sites, but in sites over fifty hectares the 'tree-bird' guild dominates in number of species, and in sites over one hundred hectares it also dominates in bird density. The 'shrub-bird' guild is the most evenly distributed in terms of species and bird density, density being lower in the larger sites. The 'ground-bird' guild increases steadily in species types and generally in bird density with site area. 'Air-birds', the smallest guild, occur throughout in very small numbers, except at the one hectare site of Warrane where they were not recorded.

The vegetation data gathered (see Chapter 3.9 for a summary) was used to compare the woodland sites for similarity. It was limited in terms of comparing guilds of birds with vegetation layers. However, it was found by regression that the average tree height strongly predicted tree-bird density (see Figure 3.24), which responded in a linear fashion to average tree height above 12 metres (r^2 = 0.67, p = 0.012). That is 67 percent of the variation in tree-bird density could be predicted by average tree-height alone. On the other hand, shrub-bird density could not be adequately predicted either by average shrub height or the average number of small stems per hectare.

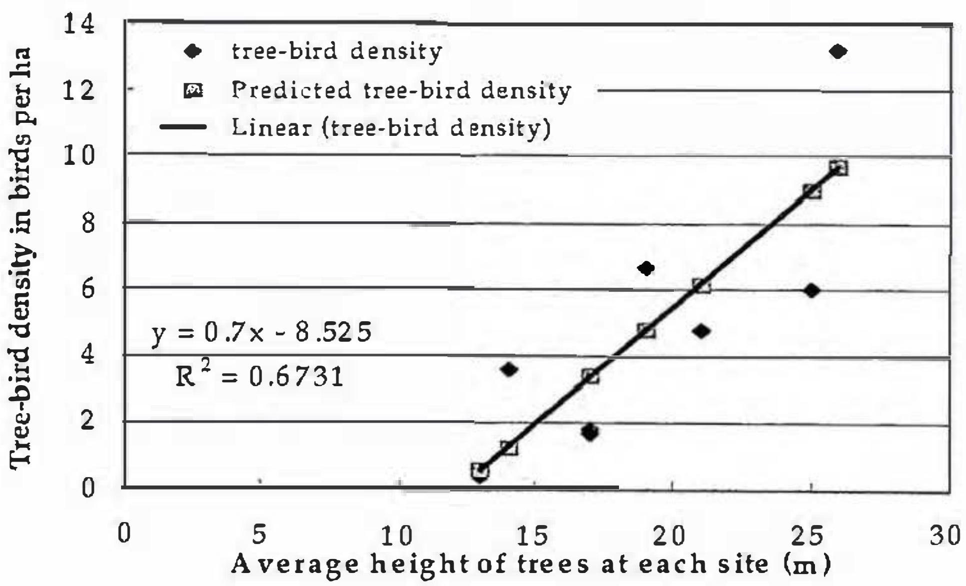

Figure 3.24 Density of 'tree-birds' in relation to average tree height.

3.9 Vegetation

All sites in this study were composed predominantly of open grassy eucalypt woodland with five dominant eucalypt tree species (see Table 3.6). White gum (*Eucalyptus viminalis*) was present in all sites, with blue gum (*E. globulus*) and black peppermint (*E. amygdalina*) present in at least half of the sites. The Risdon peppermint (*E. risdonii*) was also common at Rokeby and the Meehan Ranges while the white peppermint (*E. pulchella*) was common at Mount Rumney and less so in the Meehan Ranges. Most sites had areas of grassland ranging through to open woodland with the canopy cover never being more than about 30-40% (McDonald *et al.*, 1984). All sites had some large trees, but often these were in poor condition particularly at sites less than 80 hectares. The commonest non-eucalypt tree species was the she-oak (*Allocasuarina verticillata*), with both silver and black wattle (*Acacia dealbata* and *A. mearnsii*) being very common, although the she-oak was almost absent from the larger sites where the bull-oak (*Allocasuarina littoralis*) took its place.

Apart from wattle, the shrub layer at all sites was mostly composed of at least two of the following three species: prickly box (*Bursaria spinosa*), native hop (*Dodonaea viscosa*) and native cherry (*Exocarpos cupressiformis*).

Table 3.6 Dominant vegetation types for each site

Site	Area	Trees	Understorey	Ground
Warrane	1	Ev,Av,Ami	Av,Bs,Dv	gr
Rosny	14	Ev,Av,Ami,Bs,Dv,Ec	Av,Ad,Bs,Dv,Ec	gr,se
Natone	46	Ev,Ea,Eg,Av,Al,Ami,Ec	Av,Ad,Bs,Dv,Ec	gr,se
Gordon	52	Ev,Eg,Av,Ami	Av,Ad,Bs,Dv,Ec	gr,se
Mornington	82	Ev,Ea,Eg,Av,Ami,Dv,Ec	Av,Ad,Al,Dv,Ec,	gr,se,ep
Rokeby	160	Ev,Ea,Eg,Er,Al	Ad,Ami,Bs,Dv	gr,se,ep
Mt Rumney	800	Ev,Eg,Ep,Ami,Bs,Ec	Amn,Bs,Dv,Ec,Pa	gr,se,ep
Meehan	3,100	Ev,Ea,Eg,Er,Ep,Ec	Ad,Al,Amn,Bs	gr,se,ep

Key to Table 3.6:

Trees

Ea	= *E. amygdalina*	black peppermint
Eg	= *E. globulus*	blue gum
Ep	= *E. pulchella*	white peppermint
Er	= *E. risdonii*	Risdon peppermint
Ev	= *E. viminalis*	white gum

Trees and understorey

Ami	= *Acacia mearnsii*	black wattle
Al	= *Allocasuarina littoralis*	bull-oak
Av	= *A.verticillata*	she-oak
Bs	= *Bursaria spinosa*	prickly box
Dv	= *Dodonaea viscosa*	native hop
Ec	= *Exocarpos cupressiformis*	native cherry

Understorey

Ad	= *Acacia dealbata*	silver wattle
Amn	= *A. melanoxylon*	blackwood
Pa	= *Pomaderris apetala*	dogwood

Ground Cover

gr	= *Agrostis, Aira, Austrodanthonia, Briza, Dichelachne, Holcus, Poa, Stipa* and *Themeda* spp.	native and introduced grasses
se	= *Lepidosperma, Lomandra* and *Schoenus* spp.	sedges
ep	= *Bulbine, Epacris, Leucopogon, Senecio, Wahlenbergia* spp.	lily, epacris, heath, groundsel, bluebell

The following summary (Table 3.7) was compiled from the details of Appendix VII. The figures relate to vegetation characteristics within the quadrats selected for analysis in the transect areas of the woodland remnants. Although the transects were selected to cover all the dominant vegetation communities in the smaller sites (usually two or three), only similar communities were picked in the larger sites for comparison. However, the vegetation varies within each study site and therefore Table 3.7 is only a general comparison of vegetation features.

Table 3.7 Vegetation Summary

	No. tree species	Max tree ht (m)	Av tree ht (m)	Relative no. stems >50cm	Bitterlich wedge	No. shrub species	Av. shrub ht(m)	Relative no. stems > 2cm
SITE:								
Warrane	3	26	14	1	10	3	4	10
Rosny	6	24	13	6	17	5	6	7
Natone	7	22	17	5	8	5	5	12
Gordon	4	30	17	4	16	5	4	12
Mornington	7	30	25	3	14	5	5	10
Rokeby	5	20	19	6	24	4	4	7
MtRumney	6	40	26	3	23	5	6	4
Meehan	6	38	21	5	24	4	4	10

Table 3.7 shows that each woodland site had a similar number of dominant tree species with only five dominant eucalypts found across the study sites, *Eucalyptus viminalis* being the common link throughout all sites. Average tree height was in the range of 13 to 26 metres; with maximum tree heights in the range 20 to 40 metres. The relative stem density number for trees over 50 centimetre in circumference was in the range 3 to 6 (except the one hectare patch at Warrane). Note that these variables were picked solely to relate one site to another within this study and do not relate to any other study.

Chapter 4

Discussion

"...Empirical observations of bird populations suggest that population size is the major determinant of the short-term risk of extinction..." (Remmert, 1994).

4.1 *Introduction*

The two main parts of this study focus on the relationships between:

- the bird species richness and abundance in urban and adjacent woodland areas, and
- the bird species richness and abundance across a range of woodland remnants of different area.

The objective of the first part was to determine whether or not the woodland remnants in the study area could be considered isolated islands of habitat. The species-area relationship was then investigated to predict the 'threshold remnant area' providing maximum species richness of dry sclerophyll birds in Tasmanian woodlands. The abundance-area relationship of individual species was investigated to determine the minimum area required for some of the woodland birds of the region.

4.2 Species accumulation curves

The species accumulation curves for each site typically show a rapid rise initially and flatten out as only the rarer species are added to the list with further visits (Moverley, 1997; Minckley *et al.*,1999). In Bennett and Ford's (1997) study of birds in northern Victoria, the data used were gathered from observer lists compiled for the *Australian Atlas of Birds* (Blakers *et al.*, 1984). For a selected number of landscapes within the study region accumulative species richness was calculated and observed to rise quickly for the first ten lists (to approximately 75% of species known in the area) and then to level off towards some asymptotic level. This was done in order to compensate for differing observer effort between the landscapes in the region studied, so that the landscapes selected could be more reliably compared in other ways, for example, for species richness in different size fragments, without the confounding effect of insufficient effort in some regions. Only landscapes with at least ten observer lists were selected for further analysis in the Victorian study.

In the present study each visit to a site produced a list of species observed and as visits progressed species richness again rose to an asymptotic level usually at eight or nine visits (see Figures 3.1 to 3.8). In order to have some confidence in comparing species richness between the woodland sites, the species accumulation curves were checked for a levelling off of species indicating that the majority of birds had been seen. This appeared to be so in all cases except for Mount Rumney which, even after twelve visits, was accumulating more species (41 species). Further effort would no doubt have raised the species accumulation curve for this site to a plateau, but as this was already the most diverse site in terms of bird species, it was considered acceptable to include it in the species-area relationship test. It is also possible that the Meehan Ranges, being by far the largest area in this study, would have produced more species had the effort involved in collecting the data been more in proportion to the area of the site and spread more widely over more habitat types. It is certain that there are more than the 34 recorded species present at this site.

4.3 Comparing urban and woodland bird species diversity

Diversity is a measure of both species richness and abundance and changes in either can affect it. Figure 3.10, derived from the native and introduced bird species richness for pairs of adjacent urban and woodland sites, clearly shows a significant difference between the two environments in terms of numbers of native bird species. Although the number of introduced species is similar across all sites the quantity of introduced birds in the urban environment is very much larger than in the woodlands (see Figure 3.12). Considering that the urban transects were never more than 100 metres away from the woodland edge and similarly the woodland transects were at least 50 metres away from the edge, this considerable difference appears over a very small distance. This suggests that the woodland to urban divide is a 'hard' edge or barrier to both woodland species and, to a lesser extent, the few introduced exotic species (the main constituent of the urban avifauna). Generally, therefore, the non-native birds in the study region are more adaptable to human-induced changes in habitat than their native woodland counterparts. An exception to this appears to be the laughing kookaburra, the only non-exotic introduced bird occurring in this study, which showed a strong preference for the woodland sites. The kookaburra is perhaps more of a competitor to the original suite of woodland bird species than the introduced exotics.

It is interesting to note (see Figure 3.9) that there is only a small difference between the overall bird species richness of the smaller woodland sites of Warrane (1 hectare) and of Rosny (14 hectares) and their adjacent urban sites (an extra 3 and 7 species respectively), whereas the larger woodlands of Natone, Gordon, Mornington and Rokeby (46, 52, 82 and 160 hectares respectively) have a much greater richness in the woodland areas compared with the urban sites (15, 21, 28 and 16 extra species respectively). This suggests that smaller woodland areas are more like their surroundings, in this case the urban environment, than the larger woodland remnants and, more significantly, that there appears to be a substantial decline in woodland bird species in the adjacent urban environment.

Other researchers have referred to the increasingly negative effect of 'edge' in smaller patches of habitat (Andren and Angelstam, 1988; Harris and Silva-Lopez, 1992; Bolger *et al.*, 1997). The smaller the area of island habitat the larger the relative proportion of perimeter. At the extreme an entire patch of woodland effectively becomes 'edge' which gives preference to the generalist species at the expense of the woodland specialist species. If, for example, it is assumed that the edge effect continues for 50 metres within the woodland habitat (it may well be more or less than this) then a 100 hectare square patch of woodland is effectively reduced to 81 hectares (81%), whereas a 4 hectare square is reduced to 1 hectare (25%), and a 1 hectare patch effectively becomes just edge habitat (compare Warrane in this study). Also long narrow patches have a higher proportion of edge to area than circular or square patches. Once a landscape is reduced to fragments of the original continuous habitat, having an amount of edge is unavoidable and, in any case, probably creates a buffer zone around the inner woodland. The above example demonstrates the importance of keeping the original habitat patches as large and near round as possible. No analysis relating number of species to amount of 'edge' was made in this study, but this possibly explains the relatively depauperate nature of Rokeby, which is a long narrow area of woodland (2.5 km long x 0.9 km maximum width).

The aim of comparing urban and woodland avifauna was simply to test whether or not the remaining woodland remnants were effectively 'islands'. In terms of percentage native and introduced species found within and outside of these remnants and the apparent decline in woodland species in the urban areas, this appears to be so. A further test was to compare estimates of the woodland and urban bird populations. Significant differences in population profile were found, again based largely on a native to introduced species dichotomy, see Figure 3.11.

There have been many other studies which have also found a large change in bird composition between urban and surrounding environments. In Australia, lowered bird species richness and increases in introduced species were apparent in Sewell and Catterall's avian study in Brisbane (1998); and Wood (1996) found that introduced species decreased from 50% in the urban area of Wollongong to only 7% in an adjacent reserved area of woodland. Penland (1984, in Marzluff *et al.*, 1998) found that 'exotics' made up nearly 80% of the avifauna in the most urbanised areas of Seattle, USA. Also in America, Geis (1974) was able to monitor actual changes in avifauna as the new city of Columbia in Maryland was being developed in the 1960s and found that the variety of species declined while the absolute number of birds increased, due mainly to the increased density of the house sparrow and starling. Beissinger and Osbourne (1982) also found a reduction in bird species richness and an increase in avian biomass with increasing urbanisation in Oxford, Ohio. Crooks *et al.* (2001) found a net loss of original scrub-bird species in the habitat fragments left in the urban landscape of southern California and claimed, prophetically, that "The persistence of these native populations in the urbanising landscape depends on the persistence of the fragments themselves" (2001: 171).

4.4 Bird species composition

The ordination plot (Figure 3.14) shows clearly the difference in the bird species diversity (richness and abundance) between urban and woodland sites and the TWINSPAN classification (Figure 3.15) splits the bird species into subgroups depending on their habitat preference (divided by horizontal lines in Figure 3.15). The urban specialist group has 11 species, the generalist or 'tolerant' group 7 species and the woodland specialist group 39 species - which is further subdivided into general woodland birds, 21 species, and those that appear to require large tracts of woodland, 22 species. Note that there is some overlap from one group to another and that the noisy miner is in a group of its own in this study, appearing at only one urban and one woodland site. Although the majority (60%) of bird species recorded in this study were regularly found in small (<100 hectares) woodland and urban habitats a significant proportion

(38%) of species were recorded mostly in the larger woodlands (>100 hectares). Consequently to retain these species in the region of this study it will be necessary to preserve these large tracts of woodland, Mount Rumney and the Meehan Ranges in particular. Environment Canada (Belanger *et al.*, 1998), using birds as the indicator group, has recently categorised its woodlands by area in terms of conservation priority and has also suggested giving the highest priority to woodlands over 100 hectares.

4.5 *Bird species richness and woodland remnant area*

Since the pioneering studies of Darlington (1957), Preston (1962) and MacArthur and Wilson (1963), there have been many studies which have related the number of species to the area of isolated habitat (or island) they are found within (Diamond, 1969; Terborgh and Faaborg, 1973; Harris, 1984; Crooks *et al.*, 2001, but see Abbott, 1974, who did not find a species-area relationship in his study of the sea-birds of the islands in the Bass Strait). Often a conclusion is reached that the number of species found is doubled if the isolated area is increased by a factor of ten (Harris and Silva-Lopez, 1992). In the extremes, however, this is not the case. There are very small areas which support no species (perhaps as little as 0.1 or 1 hectare depending on the group of species in question) and also an area above which the number of species increases no further. This plateau in the species-area graph is sometimes referred to as the 'threshold' or the area at which an 'island' acts like a 'continent' (Sullivan and Shaffer, 1975). In between, the relationship has been modelled as a power curve of the form: $S=cA^k$ where S is the number of species, A the area of the habitat island, and c and k are constants (Preston, 1962), see later this section. The limits and constants of this predicted species-area relationship are themselves dependant on other factors such as the group of species being studied and the type of habitat.

Figures 3.16 and 3.17 show the number of native and total bird species plotted against the logarithm of the remnant woodland area. There is an obvious trend towards decreasing bird species richness with decreasing woodland area with a step just below 100 hectares. An explanation for this step is that this is the threshold area below which approximately ten to fifteen species of woodland birds cannot survive in this region. Fitting logarithmic or power curves to these richness/area graphs give high r^2 values (from 0.72 to 0.80) suggesting that bird species richness is strongly predicted by woodland area.

To try to understand why the Rokeby and Meehan sites show dips in an otherwise increasing relationship between bird species richness and remnant area (see Figure 3.16) they were removed and the graph replotted (see Figure 3.17). The step is still present, but the fit of the power curves give higher r^2 values (all birds = 0.92 and natives = 0.93) and hence a stronger prediction of bird species richness, the full equations being:

all birds: $S = 13.61\ A^{0.18}$

natives: $S = 9.57\ A^{0.23}$

This suggests that these two sites, being relatively depauperate in bird species, reduce the overall proportional increase in richness with area. The main difference between Rokeby and Meehan and the other six woodland sites is that they are the only sites with significant proportions of *Eucalyptus risdonii* (see Appendix VII). *E.risdonii* grows predominantly on poor to fair soils where mudstone is the substrate, and on better sites *E.amygdalina, E. viminalis and E.globulus* may also occur (Naughton, 1995). It rarely grows above 20 metres and in these two study sites grows where the ground layer is covered by a high proportion of rock. This means that where *E.risdonii* dominates, the vegetation lacks tall trees and shrubby undergrowth (de Gryse *et al.*, 1995) and hence perhaps the resources that 'tree' and 'shrub' birds need. The results show a relatively low proportion of 'shrub' bird species for Rokeby (Figure 3.21) and low overall 'shrub' and 'tree' bird density for both Rokeby and Meehan (Figure 3.22).

The peaks of diversity in this study at Mornington and Mount Rumney also pose some questions. In these cases it may be that the area given for these sites is in effect too small (160 and 800 hectares respectively). Mornington may not be so completely isolated from neighbouring Knopwood Hill by the South Arm Road and could be as much as 440 hectares, and the woodland on Mount Rumney could be contiguous with that on the hills south of Acton making it about 1,300 hectares. This may in part explain the relatively high diversity of birds found at these sites, however the shape of the curve in Figure 3.16 does not change appreciably with these modifications to site area. It is likely that more varied vegetation supports a higher diversity of birds. Mount Rumney is also surrounded by arable land rather than suburbia and this too may provide a less sharp contrast in habitat allowing a higher diversity.

4.6 Predicted area requirements for maximum bird species richness

Two studies which have attempted to relate bird species richness with patch area in the Australian woodland context have concluded that, although area has a significant effect on species richness below 20 to 30 hectares, above this area species richness does not increase appreciably (Loyn, 1987; Ford and Barrett, 1995). These studies were carried out in remnant forest vegetation in Victoria and on an agricultural landscape in New South Wales and therefore might not relate directly to an urban study in Tasmania. In another study on dry sclerophyll woodland birds in Tasmania, Bosworth *et al.* used 42 as the upper limit of bird species likely to be found (derived from a species-habitat list compiled by the Tasmanian ornithologist Thomas), which excluded migrants, nocturnal birds and included just two introduced species (laughing kookaburra and goldfinch). They concluded that the best prediction required 10,000 hectares of dry sclerophyll woodland to support 39 of these species. This area was therefore considered to be the threshold remnant area required to support most of the bird species expected to live in dry sclerophyll woodland in Tasmania, substantially larger than the predictions of Loyn and Ford for woodland birds on the mainland. The present study also predicted that bird species richness continues to increase with increasing patch size well beyond 20 to 30 hectares. Figures 3.16 and 3.17 suggest thatthe area required to support at least 40 species of birds in dry sclerophyll woodland in Tasmania is around 100 hectares. This, however, is still less than two-thirds the predicted number of species that could be present in dry sclerophyll woodland (see section 2.7).

The equations which best fit the species-area relationship in this study are similar to those derived by earlier island biogeographic studies (Preston, 1962; MacArthur and Wilson, 1967) and are of the form $S=cA^k$ (as previously mentioned, see 4.5). However, k in this study (approximately 0.17 for native species) is somewhat lower than the usual limits of 0.24 to 0.37 (Spellerberg and Sawyer, 1999: 70). With k=0.3 the original premise of Darlington (1957) is upheld, that a ten-fold increase in area will double the number of species present. With k=0.23, however, this means that a thirty-fold increase in area is required for a doubling in the number of species. If this is the case for the type of habitat islands in this study it means that much larger reserves are required to hold the same number of species than previously anticipated.

Table 4.1 Table showing theoretical predicted area for a doubling of species based on varying k

No. of Species	Area (ha)	Area (ha)	Area (ha)
	k=0.3	k=0.23	k=0.17
10	1	1	1
20	10	31.6	59
40	100	1,000	3,480

Table 4.1 shows how important the value of k is when extrapolating the species-area curve to find the minimum area required for all the species of a group in a selected habitat type (for example, all 59 native bird species in Tasmanian dry sclerophyll woodland). If, for the sake of an example, a population of ten species can survive in a one hectare patch (close to the number of species seen at Warrane - the one hectare remnant in this study), the table shows, for

different values of k, the areas required for twenty and forty species. It must be stressed that this is only a representation to highlight the sensitivity of the value of k in trying to determine the number of species that might be found in a certain area. Obviously there is a limit and that is the total number of the type of species in question that could reasonably be expected in the habitat being studied. Values of k chosen for comparison in Table 4.1 are based on: the original mid-range value of island biogeographic studies (k=0.3); the value derived for native birds in this study without the Rokeby and Meehan sites (k=0.23); and the value derived for native birds, all sites included (k=0.17).

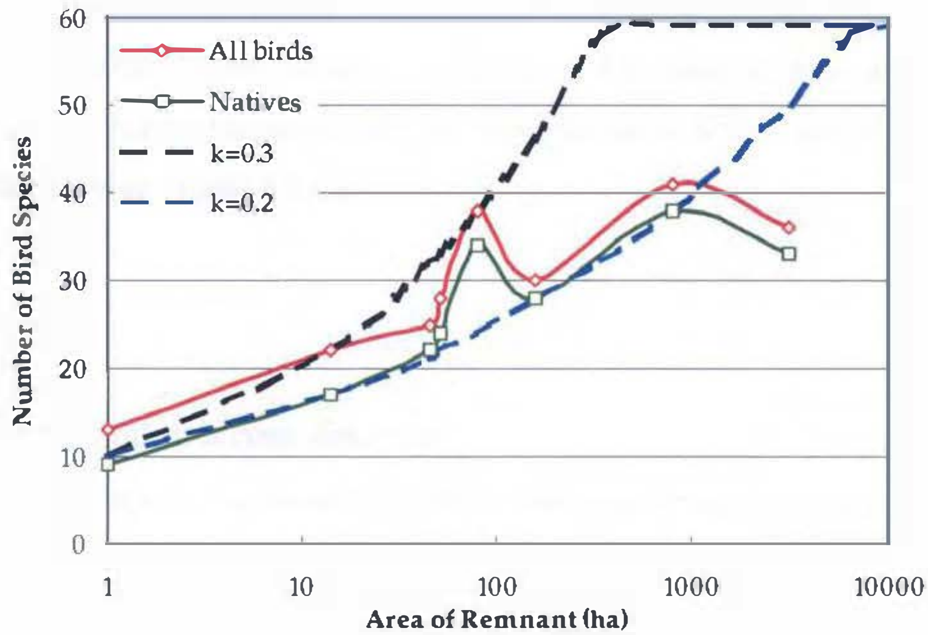

Figure 4.1 Theoretical species-area curves based on $S=cA^k$ juxtaposed with the actual curves derived in this study.

Figure 4.1 highlights the difficulty in predicting minimum area required for all species. From the results of this study it is difficult to predict whether this is 350 hectares (k=0.3), 6,500 hectares (k=0.2) or even larger (k<0.2). Likewise changes in c (the value of S where A equals one) will greatly affect the outcome. In the above example it is assumed that ten species are present in a one hectare patch *i.e.* c=10. If c is in fact less than ten then the predicted area required for maximum species richness is greater.

In the event that lower values of k more accurately predict the species-area relationship, then reserving 10,000 hectares in the hope of providing refuge for viable populations of all dry sclerophyll birds may be overly optimistic. Given the equation for native bird species-area relationship from Figure 3.18 ($S=11.12A^{0.17}$) this predicts that 14,760 hectares would be required for the full complement of 59 native dry sclerophyll bird species. Since there are few reserves of that size and habitat type in Tasmania an alternative view might be to predict how many species would be expected in certain size reserves, for example: 1,000 hectares would give 37 species and 2,000 hectares 42 species using the same equation. To ascertain which of the dry sclerophyll woodland birds are lost when large blocks of habitat are reduced in size, population densities of individual species were investigated in the different size remnants. Detectable cut-off points for some species show the area below which certain species do not survive (Table 3.5 and Figure 3.20).

4.7 Bird species population density

In this study some species were unlikely to be seen since they are not currently known to be in the Clarence City region, for example, the forty-spotted pardalote. However, 14 species were seen within this region that were not listed in this area by Thomas (1979) in the *Tasmanian Bird Atlas*. This is possibly due to some species having increased their range, for example, the Australian hobby. Two more species were seen in the study area after the end of the research period: a flock of white-throated needletails at Natone and a satin flycatcher at Mount Rumney. This increased the tally of birds seen in the region to 58, eight short of the predicted limit of 66 (see section 2.6). However, many of these were seen too infrequently to be analysed from a population density point of view.

Sections 3.6, 3.7 and 3.8 detail the use of DISTANCE software (Buckland *et al.*, 1993) to extract from the woodland data estimations of the density of: all birds; sub-groups or guilds of birds; and individual species where there were sufficient observations. Figures were derived for all sites together to give a general picture of overall bird density against site area (see Table 3.4 and Figure 3.19) which shows remarkable similarity to the general picture of bird species richness against site area (Figure 3.16). Estimations of density of the more common birds were then calculated for each site (Table 3.5). It might seem reasonable to expect that the density of a particular species would remain constant across all sites at least where the remnant area was bigger than that species individual territory requirements and the habitat remained constant. However, it is clear that where the smaller sites do fail to provide the necessary resources for the species in question, the overall diversity of the site is reduced. The three most abundant woodland native species by estimation in this study: brown thornbill (BT), yellow-throated honeyeater (YTH) and the spotted pardalote (SPP) all had small 95% confidence intervals in the estimation of density per hectare over all sites together (Table 4.2).

Table 4.2 Density of birds per hectare

Species	95% low	Best estimate	95% high
BT	1.41	1.88	2.53
YTH	0.81	1.23	1.87
SPP	0.44	0.71	1.14

Table 4.3 Population estimate range

Species	95% low	Best estimate	95% high
BT	5741	8017	10783
YTH	3436	5223	7941
SPP	1881	3015	4832

From experience in the field these do not seem unreasonable estimates of population density. In what appeared to be the most suitable habitat for the yellow-throated honeyeater (Rokeby, estimated population density 1.36 per hectare; and Mount Rumney, 2.34 per hectare) one bird was seen approximately every 100 metres. As the area surveyed was 50 metres to either side of the transect line, then, over a distance of 100 metres, this approximates to a density of one per hectare. Given that DISTANCE calculates the probability of detection to be less than 1.0 for yellow-throated honeyeaters over the studied transect width, then a more accurate density estimate will be higher than this. DISTANCE increases the density estimate, in this case to 1.23 birds per hectare.

Support for the density of the commonest woodland bird species being of the order of 0.5 to 4.0 birds per hectare is found in the literature. Of the few studies which have attempted to estimate population densities of woodland birds (none found for Tasmania), Bibby *et al.* (1989) arrived at similar figures. Using the point count census method and an earlier version of Buckland's (1987) method of estimating animal densities, they found that the three commonest woodland species in the birchwoods of Scotland: the chaffinch, willow warbler and wren, had mean population densities of 3.71, 2.68 and 1.24 respectively and accounted for about 50% of the total bird population. This compares well with the three commonest species in the dry sclerophyll woodlands near Hobart.

Emlen (1977), one of the pioneers of estimating bird population density by transect methods, determined the density of a range of birds in the mixed woods of Wisconsin in North America. The three commonest species of the 29 studied had density estimates of 1.0, (common grackle), 0.77 (American robin) and 0.6 (black-capped chickadee) birds per hectare. Again not unlike those in the current study.

Cassagrande and Beissinger (1997) conducted studies to estimate the population of a particular species of parrot in Venezuela and compared four different census methods in one 49 hectare site. The data were analysed using the DISTANCE software and the range of density estimates was 1.67 to 4.08 birds per hectare - these estimates always exceeded the known minimum population size. However, they recommended using line transect surveys for best accuracy when conditions allowed.

These references highlight the likelihood that the density figures in this study are of the right order of magnitude. Less commonly observed species will, due to the nature of how DISTANCE estimates density, have wider 95% confidence intervals, but still give reasonable figures. The species density at each site for the most commonly observed 23 species is shown in Table 3.5.

This was collated in Figure 3.20 as actual population estimates in an attempt to show where populations might cease to be viable in themselves. In island biogeographic theory a minimum viable population is reckoned to be about 20 breeding pairs, but may need to be as many as 5,000 individuals to "survive environmental stochasticity" (Ryan and Siegfried, 1993). Catterall and Roberts (1994) also suggest that small populations "in the order of tens of individuals" run a high risk of extinction due to natural events. Mac Nally and Bennett (1997), in determining bird species proneness to extinction, also highlight that there has been a large body of literature on the viability of small populations including May (1973) and Soule (1987), but do not attempt to estimate the minimum viable limit of a population.

Further analysis of Table 3.5 shows that some of the more abundant species have reasonably consistent densities spread across most sites, however, for other species it highlights where the density drops to zero at sites below a certain area. For example striated pardalotes did not occur in sites less than 50 hectares; black-headed honeyeaters were rarely observed in sites less than 80 hectares; scarlet robins had a very even density (0.27 to 0.5 birds per hectare) across all sites except those below 20 hectares. Table 4.4 shows fourteen apparently common species where the density drops to zero below a certain area.

Table 4.4 Species presence, showing absence below a certain area

Area:	1	14	46	52	82	160	800	3100
Species								
DR							X	X
BWP					X		X	X
GR					X	X	X	X
BHH					X	X	X	X
GST				X	X	X	X	X
FTC				X	X	X	X	X
STP				X	X	X	X	X
SR			X	X	X	X	X	X
BFCS			X	X	X	X	X	X
GC			X	X	X	X	X	X
GW			X	X	X	X	X	X
OW			X	X	X	X	X	X
YTH		X	X	X	X	X	X	X
GF		X	X	X	X	X	X	X

X = Species present in reasonably consistent density
Blank cells represent where there appears to be a step change in density to zero
For full species names see Appendix VI

4.8 *Bird species guilds at each site*

The results in Figures 3.21 - 3.23 show the number of species and the density of birds in each guild. Birds in the 'shrub' guild appear to show little preference for a particular site according to its size, this may be because of the small size of their own individual territory requirements (for example, superb fairy-wren, brown thornbill, olive whistler, grey fantail, and silvereye), they simply need the right kind of vegetation - shrubby undergrowth, or they move widely in nomadic groups in the winter. In this study no suitable measure was taken of the volume of undergrowth and so no correlation could be made. Shrub-bird

density could not be adequately predicted either by average shrub height or by the average number of small stems per hectare.
Birds in the 'tree' guild, however, appear to prefer larger sites above fifty hectares, both in terms of number of species and bird density, and it was found by regression that average tree height strongly predicts tree bird density, which responds in a linear fashion to tree height above approximately 12 metres (r^2 = 0.67, p = 0.012), see Figure 3.24. All sites had some large eucalypts, but the larger sites generally had taller trees, which provide more of the required resources for this guild. The Bitterlich wedge figure, a simple measure of the basal area of large tree stems taken to test for site similarity (Mueller-Dombois and Ellenberg, 1974), did not significantly correlate with tree bird density (r^2 = 0.31, p = 0.146).

'Ground' birds, excluding the introduced element, also favoured the larger sites and appeared only in very low numbers in sites of less than 80 hectares. Some of these birds (butcherbird, currawongs, magpie and raven) are for the most part large aggressive omnivores which have large individual territories. The 'air' bird group includes the large birds of prey, which also have very low population densities and high area requirements, and a few wide ranging smaller birds (dusky woodswallow, welcome swallow and tree martin).

Table 4.4 shows fourteen of the more common species of birds which appear to have some minimum area requirements, the top eleven species are all 'ground' or 'tree' birds. The smaller sites, therefore, appear not to have sufficient tree habitat or undisturbed ground area for these birds.

4.9 Study Limitations

Regardless of the research undertaken the scale, coverage and resolution could always be improved and this study was no exception. These variables are interdependent and require balance to achieve the best results in the time available. To improve the scientific worth of this study more replication of sites would have enhanced the accuracy of the findings and, coupled with a more in-depth vegetation analysis, would have facilitated investigations into avian habitat preferences. Each transect should have been placed wholly within one dominant vegetation type instead of crossing many habitat types in an effort to be efficient with time. It then proved difficult to attempt to analyse the bird data in relation to habitat based on vegetation, the approach adopted was contradicted by later findings in the literature, "transects make meaningless habitat sample units when they cross multiple cover types" (Hutto, 1998: 83). Increased observation effort in the larger sites, to allow the same chance of recording the species present as in the smaller sites, would have made the results more robust and almost certainly would have accentuated the difference in species richness between the large and small sites.

Habitat quality, which in many cases increases with increasing remnant area, is almost certainly as important as remnant area in determining biological diversity. However,in this study it was not possible to analyse this. The sites being selected initially for apparent similarity to avoid this confounding effect. In reality, a ten metre wide path cutting through a one hectare woodland will result in a far greater change in available habitat for woodland birds than a similar path in a one hundred hectare woodland. It is therefore likely that, although the vegetation was similar between sites, paths and other disturbances created a larger proportion of disturbed habitat within the smaller remnants than the larger ones.

One explanation for the very different avian richness across the woodland to urban divide is that the vegetation is markedly different between these habitats, leading to isolated populations of birds in the woodland remnants which only survive by being larger than a minimum viable population necessary for continued survival. However, there has been much research into meta-populations where a whole population of a particular species is made up of sub-populations which are not isolated within islands, but able to migrate between them (Spellerberg and Sawyer, 1999). Birds are generally one such group able to migrate large distances for their size and so it is perhaps surprising to find reduced species richness and abundance in small woodland remnants, isolated from a large tract of woodland by only a few kilometres, as in this study.

An extension of the meta-population theory is source-sink population dynamics, where large islands of good quality habitat (sources) support breeding birds some of which then disperse to smaller islands of lesser quality habitat within the same region. The smaller islands become population sinks, being less able to support the immigrants, not only due to reduced habitat availability, but also due to increased competition, predation and disturbance. These theories suggest a dynamism to animal populations that a simple area-diversity study such as this will mask (Spellerberg and Sawyer, 1999). Area is obviously not the sole variable upon which the optimal size and success of an animal population depends, but much literature suggests that it is of great significance and therefore studies which focus on this should not be overlooked. They set a baseline from which changes in diversity can be detected in the future and can highlight problems in methodology before further research is embarked upon.

Chapter 5

Conclusion

"Conservation biology theory and practice often focus on retaining maximal species richness, but the worth of a small habitat fragment should not be gauged solely by how many species it can retain. Other ...values of natural areas include the education of the general public, research by scientists, use as landscape benchmarks or monitoring sites and establishment of natural heritage museums." (Shafer, 1995).

The first aim of this study was to test for differences in avian diversity in woodland remnants and the surrounding urban environment. The results show a substantial decline in native bird species diversity from an average of 95% of all bird species in the woodlands to only 15% in the urban environment. In numerical terms the woodland sites ranged from 10 to 34 native bird species and the adjacent urban sites from 3 to 9 native species.

The population profile of the bird assemblage in these habitats also varied widely. In the urban sites the two most common species accounted for 68% of sightings (common starling 38% and house sparrow 30%), but in the woodland sites the two most commonly observed species accounted for 28% (brown thornbill and silvereye, both 14%). All five of the most abundant species in the woodlands were native species (two of which are endemic to Tasmania, yellow-throated and black-headed honeyeaters), whereas four of the top five species in the urban areas are exotic species (the only native being the little wattlebird, ranked fourth). It is clear that if these woodlands continue to be turned into urban landscapes then the disappearance of woodland bird species, which will certainly follow, will include some of the Tasmanian endemic species.

These significant changes in the bird assemblages allowed the range of woodland remnant sites to be considered as islands in the urban domain and therefore their area-to-species relationship could be investigated. Generally it was found that the bird species diversity reduced as the remnant area reduced, but this was not always the case. The Meehan Range site, which was selected to be one of the two large reference areas, appeared to be relatively depauperate for its size. This could be due to a number of factors, but most probably because this woodland is lacking in some aspects of vegetation structure, for example, undergrowth and hence the species that require that habitat type. It is also probable that the transects selected for the larger sites in this study did not give adequate coverage to allow detection of most bird species likely to be present.

Overall density of birds per hectare was found to change with area, but not in a linear fashion. Sites above 50 hectares recorded an average density of around 15 birds per hectare whereas below 50 hectares the density dropped to 6 to 7 birds per hectare. This reduction is due as much to the quality of the remaining habitat as to the site area itself. Habitat quality being inherently poorer in the smaller sites due to a higher percentage of edge area (and its associated negative effects) and the greater proportion of area that tracks and pathways take up in the smaller sites.

A study of the density of some of the more abundant species revealed that some species appear to require suitable habitat larger than a certain minimum area, for example, the dusky robin (another Tasmanian endemic) was not recorded in any site less than 800 hectares, but the scarlet robin was found in sites down to around 50 hectares. Two other endemic and normally abundant species, the black-headed honeyeater and green rosella, were only recorded in reasonable density in sites over 80 hectares. Other birds which were not recorded in sites of less than about 50 hectares were: grey shrike-thrush, fan-tailed cuckoo, striated pardalote, black-faced cuckoo shrike, grey currawong, golden whistler and olive whistler.

A comparison of the densities of the three most abundant woodland birds in this study, 0.71 to 1.88 birds per hectare, compares well with the most abundant woodland birds in two other studies and gives some credence to the population estimates at least for the more common species. It is, however, clear that extrapolating a density estimate to a population figure for a whole site will not give an accurate result if the habitat varies substantially throughout the remnant. With better coverage at a higher resolution of transects these figures would no doubt be improved.

It is interesting to note that, if the most common woodland bird species have a density of around one bird per hectare and the minimum viable population estimate of around 20 breeding pairs is to be believed, then any remnant of less than 40 hectares will not support even the most common species in the long term. However, Shafer (1995) in his defence of small reserves, considers that reserves of less than 40 hectares "continue to fill a worthy niche in conservation strategies for preserving biological diversity". Whereas the focus has been on large reserves as the best way to preserve maximum biodiversity he points out that small reserves may contain species not found in any large reserve and therefore that "(biological) inventory detail is becoming necessary in highly human-impacted landscapes (to stop certain species) from being lost through ignorance" (Shafer, 1995: 85). This highlights the necessity of studies such as the present one to catalogue biodiversity to give managers the information they require to determine what is best preserved.
It could be said that baseline studies of avian diversity and population are perhaps the most important use of observation effort and resources in the field of conservation biology at the present time.

As overall destruction of original natural habitat has already reached more than 90% in some regions of Australia (see Bennett and Ford, 1997: 249) preserving any remaining habitat is becoming increasingly important regardless of size, even if it is not known exactly what that habitat supports. However, given that ignorance of these details will mask any changes that are occurring in bird populations, even just beyond our own doorsteps, obvious indicators of the state of the environment will be missed. Without attempting to redress this ignorance we are like the miner ignoring the canary.

It is obviously important to set aside large reserves for the continued persistence of many species, but predictions that small reserves are not worth saving (Simberloff, 1988) are somewhat wide of the mark. They clearly do support some species in their own right and provide stepping stones for nomadic and migratory species between large reserves. It would perhaps be better to suggest that we do not make small reserves out of large ones.

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Appendices

Appendix I Winter summary woodland bird count.

Numbers of native birds recorded in woodland sites in winter

SITE	Warrane	Rosny	Natone	Gordon	Morn'ton	Rokeby	Rumney	Meehan	Total
Native species	1	14	46	52	82	160	800	3100	4255
BG									
WBSE									
WIE									
SH									
BF							xxxx1		1
AH				xxxx1	xxp1x				2
CBW						xxpx			p
BBW					xxx1x				1
YBC							pxxxx		p
SCC							xx5x1		6
ML	xxp					x2px	pxxxx		2
GR					x p132	x136	122921	3 5 2 x	52
ER						xxx2			2
BWP									
PC								x x x p	p
FTC							xxx11	x 1 x 2	5
HBC									
SBC									
SFW			1xxx		6xxx3		xxxx1	6 x x 2	19
SPP	21x	x1xx1	2x36	xxx1x	3x124	7523	23951	2 2 4 3	75
SIP					xxxx1			x x x 3	4
BT	x2x	4422x	6426	34845	37888	41125	6xx4x	631210	153
YRT			xxx2	x2xxx					4
LW				xx1xx	1xxxx				2
YW	xx1		1xx2		xxxp1	xxx1	xxx1x		7
NM						5416			16
YTH		21x1x	2233	xxx21	3145x	8896	2114129	6 3 8 7	123
SBH			xxx1				xx2xx	1 x x p	4
BHH			xxx2		251x1x	10xxx	7x12139	824165	133
NHH									p
CH		x11xx			xxx1x		xxx13	1 x x x	8
ES			1xxx		xxx11			x x 1 x	4
FRO									
SR			2x22	11312	1x142	1112	xxxx2	2 x 6 5	42
DR							21x1x	x 2 x x	6
OW		1xxx1		11111	3p2x4	xx1x		x x 1 x	18
GW			p11x	xxx1x	1xxxx	xx1x	xxx21	2 x 1 2	13
GST				xx1xx	xxx3x	1x11	211xx	x x 1 8	20
GF		11xxx	px1x	x1xxx	xxx42	xxpx		x x x p	10
BFC			xxx1		pxxxx				1
GB		xxxx1	xx1x		pxxpx	xxx1			3
AM						x2xx			2
BC									
GC			1xxx		pxxx1	1xpx		2 x x 1	6
FRA		1x322	122x	xxx11	xx233	x2x2	xx942	x 1 x 3	46
DWS									
WS									
TM								x x x 2	2
SE		x30125x6	6x3x	x188x2	xxxx3				201
Native species									
Species in transects	3	9	17	13	21	17	17	19	36
Species at site	4	9	17	13	23	19	19	21	38
Total no. of natives	6	194	75	78	146	129	180	185	993

p = present at site but not in the transects x = not recorded

Appendix I Winter summary woodland bird count

Numbers of introduced birds recorded in woodland sites in winter

	Warrane	Rosny	Natone	Gordon	Morn'ton	Rokeby	Rumney	Meehan	Total
STD			21xx						3
LK								1 x x 1	2
GOF	x2x	31x1x	3x1x	xxx3x	xxxp1	1xxx		1 x x x	17
GRF		x6xx							6
HS	xx1						xx3xx		4
BB		xxx11	xx1x		1xx22				8
CS	x2x	1xx1							4
ALL BIRDS									Totals
Species in transects	6	13	20	14	23	18	18	21	43
Species at site	7	13	20	14	25	20	20	23	45
Total number of birds	11	209	83	81	152	130	183	188	1037

Appendix II Spring summary woodland bird count

Numbers of native birds recorded in woodland sites in spring

SITE	Warrane	Rosny	Natone	Gordon	Morr'ton	Rokeby	Rumney	Meehan	Total
Native species	1	14	46	52	82	160	800	3100	
BG									
WBSE							xx1x		1
WIE					1xxx		xxpx		1
SH						x2xx			2
BF					xxpx		1xxx	x1xx	2
AH		1xxx			xxx1				2
CBW						xxpx		x1xx	1
BBW									
YBC		xx4x		pxxx			xxpp		4
SCC							31px	pxxx	4
ML					x2xx				2
GR			xx1x	xxxp	1x1x	2xxx	7634	1121	30
ER					121x	xx2x	3x1x		10
BWP					215x		676x	xx14	32
FC				xpxx	1p2x	1xpp	2xx1	2xp2	11
FTC						1122	x222	7244	29
HBC					12xx		xx1x	1xxx	5
SBC				xx1x			xx11	px13	7
SFW	x4xx		xx1x		x285		x1x1	p362	33
SPP	xx1x		xpxx		1114	5243	5735	1211	47
STP				2672	9553	xxx1	8111213	9101110	122
BT		x2x1	16xx	3714	10367	8615	36xx	8484	104
YRT			xpxx		xx1x				1
LW	x1xx	x2xx		xxx2					5
YW	1x1x	x11x	3x34	xx2x	pxxx	411x	x1xx		23
NM						11552			23
YTH		x1xx	2xxx	2322	135x	7644	1 1389	5334	98
SBH							xxx8	xpxx	8
BHH					14x1	xx1x	3x97	83x2	39
NHH					xppx				p
CH									
ES									
FRO								1131	6
SR				111x	1x12	16xx	xxpx	11x2	18
DR							x2x1	x1xx	4
OW						xx1x		p1xp	2
GW							xxx1	2321	9
GST				1x11	x1xx	x2pp	x214	5332	26
GF		xxx1		p2xp	8635	xxxp		x112	29
BFC		xpxx	11102	3412	44x4	4573		x1xx	56
GB	xx1x	1xxx	1112	pxxx		2x1x			10
AM									
BC							xxpx		p
GC		x11x	xx24	xxx2	1xpp	332x	xpxx	2111	24
FRA		xx64	6121	1xx1	x3p2	8241	533x	p111	56
DVS			xp1x	5xx2	574x	1xxx		4xxx	29
WS			xxx2		pxxx		xxpx		2
TM		x2x1	xxx2			xxx20	6x2214	2p210	81
SE	31x1	1920128	2p25	3457	12p99	xxpp		2111	127
Native species									
Species in transects	6	12	13	14	23	21	23	27	42
Species at site	6	13	15	18	27	24	29	29	45
Total no of natives	14	69	62	102	201	175	261	215	1126

Appendix II Spring summary woodland bird count

Numbers of introduced birds recorded in woodland sites in spring

	Warrane	Rosny	Natone	Gordon	Morn'ton	Rokeby	Rumney	Meehan	Total
STD									
LK				1 1x1	1x1x		xxx1	x1px	7
GOF	x2xx		xxx2	x1xx	12xx	pxx2			10
GRF		xxxp							p
HS	x2x1	xxxp		xxxp	xpxx				3
BB	1322	1222	x122	12x8	xp23	pxxx			36
CS	2161x				x54x				28
ALL BIRDS									
Species in transects	10	13	15	17	27	22	24	28	47
Species at site	10	16	17	22	32	26	30	30	51
Total birds	46	96	69	117	220	177	262	216	1209

Appendix III Summer summary woodland bird count

Numbers of native birds recorded in woodland sites in summer

SITE	Warrane	Rosny	Natone	Gordon	Morn'ton	Rokeby	Rumney	Meehan	Total
Native	1	14	46	52	82	160	800	3100	
BG							x 1 x		1
WBSE									
WTE					x x x 1		x x p		1
SH									
BF							x 2 x		2
AH									
CBW									
BBW									
YBC							x p x	x p x x x	p
SCC							x 3 p	p x x x x	3
ML					x x 1 2	1 1 x 1			6
GR						x x 2 2	2 1 8	p x x 1 2	18
ER									
BWP					1 x x x		x 6 5		12
PC									
FTC		x x 1		1 1 x x	1 1 x x	1 x x x	x 1 x	x x x 1 1	9
HBC									
SBC									
SFW					x 2 3 x		x 3 x	x x x 4 1	13
SPP			x x 3	x x 5 x	6 2 1 2	1 1 9 1	3 7 5	6 x 2 2 4	60
STP					x x 1 1	5 2 x x	15 8 x	x 1 x x 1	34
BT	x 1 x	2 2 x	x x 2	1 x 2 6	4 6 8 4	4 4 5 6	x x 2	12 3 7 10	107
YRT						x x x 4			4
LW									
YW	x 1 x	x x 1	x x 8	x x x 1	x x x 1	1 3 x x		x 3 1 x x	20
NM						2 2 x 2			6
YTH	x 1 x	p 2 x	1 2 1	2 3 2 1	7 2 1 3	5 2 7 3	7 13 7	3 7 1 7 5	95
SBH								x x x 5 2	7
BHH,					11 1 x 1	x x x 8	3 19 5	4 1 4 1 4	62
NHH									
CH							1 x x		1
ES								1 x x x x	1
FRO							x 1 1		2
SR				2 x 1 x	1 1 4 1	2 1 3 1	2 2 4	4 1 x x 3	33
DR							x 3 x	x x 3 4 x	10
OW			x x 1	x 2 x x	x x x 1		2 x 2	x x x x 1	9
GW					1 x x x			x 1 1 1 1	5
GST				x 2 x x			5 4 2	x p x x 1	14
GF		2 x x		x x x 1	3 2 1 2	x x 1 3	x 4 2	1 1 1 4 2	30
BFC			x p x	1 x x x		x 1 3 3	x1 3	x 2 2 x x	16
GB		x 1 x	2 x 1		x 1 1 1	2 x x x	x x 1		10
AM									
BC									
GC		x 2 x	1 x x	x x 2 x	x 1 x p		x x p	p 4 x x 1	11
FRA		x 1 x	x x 8	x p x x	1 x x 3	1 x x 2	1 5 3	x p p x 2	26
DWS									
WS									
TM			x 4 x				x 3 x		7
SE	x x 2	1 13 2	2 x x	1 12 x 1	15 x 1 4	1 1 1 1	x x 5	3 1 1 4 1	75
Native									
Species in transects	4	9	10	12	19	17	24	21	33
Species at site	4	9	11	13	19	17	27	23	34
Total no. of natives	5	30	57	75	118	112	183	177	757

Appendix III Summer summary woodland bird count

Numbers of introduced birds recorded in woodland sites in summer

	Warrane	Rosny	Natone	Gordon	Morn'ton	Rokeby	Rumney	Meehan	Total
STD									
LK				x 1 x x	1 x x x		x x p	x x 2 x 1	5
GOF	x 1 x	3 2 1		3 9 x x	2 x x x		x x 1		22
GRF									
HS									
BB			1 x x	x 1 x x	1 x x x			x x x x 1	4
CS									
ALL BIRDS									
Species in trans	5	10	11	15	22	17	25	23	36
Species at site	5	10	12	16	22	17	29	25	39
Total birds	6	36	58	89	122	112	184	181	788

Appendix IV Winter summary urban bird count

Numbers of native & introduced birds recorded in urban sites in winter

Urban winter summary	Urban street: near site:	Ninda Rosny	Raminea Natone	Kaoota Gordon	Binalong Morn'ton	Elinga Rokeby	Total no. of species
Natives:							
ML						p x x x	p
ER						2 x x x	2
LW		2 3 3 3	x 2 1 x	3 2 2 1	2 x x x	1 1 3 1	30
YW		x x x 1	x 1 x x		1 x x x	x 1 x x	4
NM						x 4 7 4	15
YTH		1 x x x					1
NHH		x 2 x 1		x x 1 2	2 x x 2	x x 1 1	12
CH		x 1 1 2	x x 1 x		1 1 2 x		8
ES			p x x x				p
BFC							
GB		x 1 x x	x x x 1				2
AM		x 3 x 1					4
GC					1 x x x	x 6 6 x	13
FRA							
WS							
SE		x x 6 x					6
Introduced							
STD					1 x x 1	x 6 3 2	13
LK							
GOF						x x x 3	3
GRF							
HS		2 4 1 5	4 x 3 7	x 5 2 31	3 1 3 12	2 x 1 2	88
BB		x 3 2 5	2 x 1 x	x x 1 2	3 3 3 2	2 2 1 2	34
CS		20 3 1 5	9 12 10 9	31 8 21 1	1 2 7 5	13 8 4 1	171
Native species		8	4	2	5	6	11
Total species		11	7	5	9	11	16
Total no. native		31	6	11	12	38	98
Total introduced		51	57	102	47	52	309

Appendix V Spring summary urban bird count

Numbers of native & introduced birds recorded in urban sites in spring

Urban spring summary	Urban street: near site:	Ninda Rosny	Raminea Natone	Kaoota Gordon	Binalong Morn'ton	Elinga Rokeby	Total no. of species
Natives:							
ML							
ER						x 1 x	1
LW		1 x x		x 2 2	2 1 2	1 x x	11
YW		x 1 1	1 1 1		2 x x		7
NM						1 3 x	4
YTH							
NHH							
CH							
ES							
BFC		1 x x					1
GB					x 1 x		1
AM		1 x x					1
GC							
FRA							
WS						x 1 x	1
SE			x x 1	1 1 x			3
Introduced							
STD						1 2 1	4
LK							
GOF		x x 2	x x 1	5 13 x		7 3 1	32
GRF							
HS		6 16 24	13 7 8	2 9 14	9 3 11	4 5 4	135
BB		2 2 3	x 1 3	2 1 2	2 1 1	4 2 2	28
CS		x 2 4	6 6 15	3 21 3	6 9 5	8 7 6	101
Native species		4	2	2	3	4	9
Total species		8	6	6	6	9	14
Total no. native		5	4	6	8	7	30
Total introduced		61	60	75	47	57	300

Appendix VI

Bird codes, names and habitat preference.

Bird Code	Common name	Scientific name	Preferred Guild
BG	Brown goshawk	*Accipiter fasciatus*	t
WBSE	White-bellied sea eagle	*Haliaeetus leucogaster*	a
WTE	Wedge-tailed eagle	*Aquila audax*	a
SH	Swamp harrier	*Circus approximans*	a
BF	Brown falcon	*Falco berigora*	a
AH	Australian hobby	*Falco longipennis*	a
CBW	Common bronzewing	*Phaps chalcoptera*	g
BBW	Brush bronzewing	*Phaps elegans*	g
YBC	Yellow-tailed black-cockatoo	*Calyptorhynchus funereus*	t
SCC	Sulphur-crested cockatoo	*Cacatua galerita*	g
ML	Musk lorikeet	*Glossopsitta concinna*	t
GR	Green rosella	*Platycercus caledonicus*	t
ER	Eastern rosella	*Platycercus eximius*	t
BWP	Blue-winged parrot	*Neophema chrysostoma*	g
PC	Pallid cuckoo	*Cuculus pallidus*	t
FTC	Fan-tailed cuckoo	*Cacomantis flabelliformis*	g
HBC	Horsfield's bronze-cuckoo	*Chrysococcyx basalis*	s
SBC	Shining bronze-cuckoo	*Chrysococcyx lucidus*	s
SFW	Superb fairy-wren	*Malurus cyaneus*	s
SPP	Spotted pardalote	*Pardalotus punctatus*	t
STP	Striated pardalote	*Pardalotus striatus*	t
BT	Brown thornbill	*Acanthiza pusilla*	s
YRT	Yellow-rumped thornbill	*Acanthiza chrysorrhoa*	g
LW	Little wattlebird	*Anthochaera chrysoptera*	s
YW	Yellow wattlebird	*Anthochaera paradoxa*	s
NM	Noisy miner	*Manorina melanocephala*	t
YTH	Yellow-throated honeyeater	*Lichenostomus flavicollis*	t
SBH	Strong-billed honeyeater	*Melithreptus validirostris*	t
BHH	Black-headed honeyeater	*Melithreptus affinis*	t
NHH	New Holland Honeyeater	*Phylidonyris novaehollandiae*	s
CH	Crescent honeyeater	*Phylidonyris pyrrhoptera*	s
ES	Eastern spinebill	*Acanthorhynchus tenuirostris*	s
FRO	Flame robin	*Petroica phoenicea*	g
SR	Scarlet robin	*Petroica multicolor*	g
DR	Dusky robin	*Melanodryas vittata*	g
OW	Olive whistler	*Pachycephala olivacea*	s
GW	Golden whistler	*Pachycephala pectoralis*	t
GST	Grey shrike-thrush	*Colluricincla harmonica*	t
GF	Grey fantail	*Rhipidura fuliginosa*	s
BFCS	Black-faced cuckoo-shrike	*Coracina novaehollandiae*	t
GB	Grey butcherbird	*Cracticus torquatus*	g
AM	Australian magpie	*Gymnorhina tibicen*	g
BC	Black currawong	*Strepera fuliginosa*	g
GC	Grey currawong	*Strepera versicolor*	g
FRA	Forest raven	*Corvus tasmanicus*	g
DWS	Dusky woodswallow	*Artamus cyanopterus*	a
WS	Welcome swallow	*Hirundo neoxena*	a
TM	Tree martin	*Hirundo nigricans*	a
SE	Silvereye	*Zosterops lateralis*	s
STD*	Spotted turtle-dove	*Streptopelia chinensis*	g
LK*	Laughing kookaburra	*Dacelo novaeguineae*	g
GOF*	Goldfinch	*Carduelis caeduelis*	g
GRF*	Greenfinch	*Carduelis chloris*	g
HS*	House sparrow	*Passer domesticus*	g
BB*	Blackbird	*Turdus merula*	g
CS*	Common starling	*Sturnus vulgaris*	g

* = introduced, g = ground, s = shrub, t = tree, a = air

Appendix VII

Vegetation survey by site.

		Site:	Warrane	Rosny	Natone	Gordon	Mornington	Rokeby	MtRumney	Meehan
Species:										
Eucalyptus	*amygdalina*	stems>50cm circ/ha			92		100	150[117]		213[6]
		stems>2cm diam/ha			17[17]		0	92[8]		50
		Bitterlich			7,1,x		0,10[1]	10,12,8		17,9,1,13
		Height			18,15,x		25,28	19,17,20		22,22,12,18
Eucalyptus	*globulus*	stems>50cm circ/ha			[8]	50	x	8	75	31[6]
		stems>2cm diam/ha			0	0	x	x	17	0
		Bitterlich			[1],x,x	x,x,6	0,1	1,1,x	2,4,x	2,2,6,[2]
		Height			[30],x,x	x,x,23	x,26	?,20,x	40,38,43	27,38,30,[35]
Eucalyptus	*risdonii*	stems>50cm circ/ha						58		81
		stems>2cm diam/ha						42		275
		Bitterlich						x,6,11		x,7,13,x
		Height						x,17,18		x,20,23,x
Eucalyptus	*viminalis*	stems>50cm circ/ha		44[75]	208[25]	108[17]	38	225	67[17]	113[6]
		stems>2cm diam/ha	50[75]	6	8	125[8]	25[25]	175[8]	50[58]	25
		Bitterlich	4,2	1,[2],1[2],[2]	2,10,2	7[1],12,4	5[3],2	8,5,8	10,x,2	6,5[1],5,6
		Height	14,26	14,12,24,15	22,16,15	17,24,30	8-30,20	20,19,18	30,x,30	30,20,20,20
Eucalyptus	*pulchella*	stems>50cm circ/ha							108[17]	6
		stems>2cm diam/ha							42	0
		Bitterlich							1[1],18[1],14[3]	x,x,1,x
		Height							10,22,37	x,x,15,x
Allocasuarina	*verticillata*	stems>50cm circ/ha	75[25]	494[31]	25	175	50[25]			
		stems>2cm diam/ha	250[300]	313[6]	175	217	[38]			
		Bitterlich	3,8	16,17,12,14	x,x,x	2,3,13	[1]			
		Height	8,9	10,14,12,12	?,?,?	11,9,11	?,7			
Allocasuarina	*littoralis*	stems>50cm circ/ha			25		x	42		0
		stems>2cm diam/ha			25		25[13]	125		13
		Bitterlich			x,x,x		x,x	x,2,x		x,x,x,x
		Height			?,?,?		x,4	2,8,4		x,2,x,?
Acacia	*dealbata*	stems>50cm circ/ha		0	0	0	x	x		0
		stems>2cm diam/ha		19	508[25]	317	188[175]	108		156
		Bitterlich		x,x,x,x	x,x,x	x,x,x	x,x	0,x,0		x,x,x,x
		Height		x,x,7,x	4,3,4	?,5,?	5,4	?,?,2		3,2,x,2
Acacia	*mearnsii*	stems>50cm circ/ha		38	67	33	25	x	33	
		stems>2cm diam/ha	25	6	108	58	x	17	67	
		Bitterlich	x,3	1,0,0,2	x,1,x	1,x,x	x,1	x,x,x	4,x,7	
		Height	12,4	12,x,x,11	x,8,8	11,x,8	?,20	4,x,5	10,x,6	
Acacia	*melanoxylon*	stems>50cm circ/ha							x	0
		stems>2cm diam/ha							92	6
		Bitterlich							x,x,x,	x,x,x,x
		Height							x,5,x	1.5,x,x,x
Exocarpus	*cupressiformis*	stems>50cm circ/ha		19	33	0	x		x	38
		stems>2cm diam/ha		44	67	33	25,[13]		25	0
		Bitterlich		0,0,0,1	1,x,1	x,x,x	2,1		x,1,x	1,1,x,x
		Height		x,x,x,6	6,3,5	x,2,x	4,7		x,4,x	12,12,8,8
Bursaria	*spinosa*	stems>50cm circ/ha		19	0	0		x	x	b
		stems>2cm diam/ha	75	213	17	125		33	50	6
		Bitterlich		x,x,x,x	x,x,x	x,x,x		x,x,x,	2,x,2	x,x,x,x
		Height	x,3	?,8,5,?	?,?,?	3,?,3		2,x,?	8,x,5	x,x,2,x
Dodonaea	*viscosa*	stems>50cm circ/ha		13	0	0	37	x	x	
		stems>2cm diam/ha	[200]	131	217	325	488,[many]	117	x	
		Bitterlich		x,x,x,x	x,x,x	x,x,x	13,x	x,x,x	x,x,x	
		Height	x,4	?,?,?,?	4,?,?	4,3,3	7,4	3,x,2	x,x,8	
Pomaderris	*apetala*	stems>50cm circ/ha							x	
		stems>2cm diam/ha							8	
		Bitterlich							x,x,x	
		Height							x,2,x	

x = not present in sample ? = not measured in sample [n] = no. of dead stems

Appendix VIII

Vegetation species occurring at each site

Scientific name	Type	max ht	Status	Common name	war	ros	nat	gor	mor	rok	mtr	mee
?				moss		X		X	X		X	
Acacia dealbata	s/t	33		Silve wattle		X	X	X	X	X	X	X
Acacia genistifolia	s	3		Spreading wattle			X					X
Acacia mearnsii	t	10		Black wattle	X	X	X	X	X	X	X	X
Acacia melanoxylon	t	30		Blackwood							X	X
Acacia stricta	s	1.5					X					
Acaena echinata	h	0.6								X		
Acaena novae-zeelandiae	h			Buzzy							X	
Adiantum aethiopicum	f	0.5		Maidenhair fern		X						
Agrostis aemula	g	0.65		grass	X	X	X	X	X	X	X	X
Aira elegans	g	0.5	*	grass		X				X		
Aira sp.	g			grass	X	X	X	X	X	X	X	X
Allocasuarina littoralis	t	7		Bull-oak			X		X	X		X
Allocasuarina verticillata	t	7		She-oak	X	X	X	X	X			
Anagallis arvensis	h	0.4	*	Pimpernel							X	
Aotus ericoides	s	1.3		Golden pea					X			
Arrhenatherum elatius	g	1.5	*	Onion-twitch			X		X		X	
Arthropidium milleflorum	h	1							X			
Aster sp.	h	0.2	*	European daisy				X				
Astroloma humifusum	s	0.4		Native cranberry		X				X		X
Austrodanthonia caespitosa	g	0.9		Wallaby grass								X
Austrodanthonia setacea	g	0.6		Wallaby grass						X		
Austrodanthonia sp.	g	1		Wallaby grass	X	X	X	X	X	X	X	X
Avena fatua	g	1.2	*	grass	X	X	X	X				
Banksia marginata	s/t	9		Honeysuckle					X			
Beyeria viscosa	s/t	9		Pinkwood				X				
Bossiaea cinerea	s	1.2		pea		X			X			
Bossiaea prostrata	s	0.3		pea						X		
Brachyscome angustifolia	h			daisy						X		X
Brassica sp.	h	1	*		X							
Briza maxima	g	0.6	*	Quaking grass	X			X	X			
Briza minor	g	1.6	*	Lesser quaking grass			X			X		
Bulbine bulbosa	h	0.5		Bulbine lily		X		X				
Bulbine glauca	h	0.9		Rock lily				X				
Bursaria spinosa	s/t	13		Prickly box	X	X	X	X		X	X	X
Cassinia aculeata	s	4		Dolly bush							X	
Centaurium erythraea	h	0.5	*	Common centaury				X		X	X	
Centaurium tenuiflorum	h	0.2	*	Centaury						X		
Chrysanthemoides monilifera	s	2	*	Bone seed	X	X	X	X	X	X		
Chrysocephalum apiculatum	h	0.5		Common everlasting	X	X		X	X			
Cirsium vulgare	h	1.5	*	Spear thistle						X	X	
Comesperma volubile	s			Blue love-creeper			X	X		X	X	
Coprosma quadrifida												X
Cotoneaster sp.	s/t		*	Cotoneaster		X		X				
Cyathodes juniperina	s	2		Pink berry								X
Cynosurus echinatus	g		*	grass				X	X	X		
Dactylis glomerata	g		*	Cocksfoot	X	X		X	X			
Daviesia latifolia	s	2		Bitter leaf			X			X		
Daviesia ulicifolia	s			pea								X
Deyeuxia quadriseta	g			grass				X	X	X	X	
Dianella longifolia	h			Paleflax lily		X				X		X
Dianella revoluta	h			Blue flax lily	X		X	X		X		
Dichelachne crinita	g			grass		X	X	X	X	X	X	
Dichondra repens										X		
Dillwynia cinerascens	s	0.8		Parrot pea			X	X				
Dillwynia glaberrima	s	1.2		Parrot pea			X	X	X			
Diuris longifolia	h	0.45		Wallflower orchid			X			X		
Dodonaea viscosa	s	6		Native hop	X	X	X	X	X	X	X	X

Appendix VIII

Vegetation species occurring at each site

Scientific name	Type	max ht	Status	Common name	war	ros	nat	gor	mor	rok	mtr	mee
Elymus scaber	g	1.2		grass						X		
Epacris impressa	s	1		Common heath				X	X	X	X	X
Epacris lanuginosa	s	0.9		Swamp heath							X	
Eucalyptus amygdalina	t	30	e	Black peppermint			X		X	X		X
Eucalyptus globulus	t	70		Blue gum			X	X	X	X	X	X
Eucalyptus pulchella	t	21	e	White peppermint			X				X	X
Eucalyptus risdonii	t	20	e	Risdon peppermint						X		X
Eucalyptus viminalis	t	70		White gum	X	X	X	X	X	X	X	X
Euchiton collinus	h	0.4		Cudweed	X					X		
Euchiton involucratus	h	0.4		Cudweed	X					X		
Exocarpos cupressiformis	s/t	8		Native cherry		X	X	X	X	X	X	X
Galium sp.	h		*?	Goosegrass						X		
Gnaphalium sp.	h	0.4		Cudweed	X							
Gonocarpus tetragynus	h	0.5		Raspwort		X	X			X		X
Helichrysum scorpioides	h	0.4										X
Holcus lanatus	g	1	*	Yorkshire fog		X	X	X	X	X	X	
Hypochaeris radicata	h	0.6	*	Cat's ear	X		X	X	X		X	
Leontodon taraxacoides	h		*	Hairy hawkbit		X						X
Lepidium sp.	h	0.5		Cress				X	X			
Lepidosperma sp.	h	1		Sedge							X	
Lepidospermum concavum	h	1		Sedge					X			
Leptomeria drupacea	s	2.5										X
Leptorynchos squamatus	h	0.2		Scaly buttons			X	X		X	X	
Leucopogon collinus	s	0.6		Bearded heath							X	
Leucopogon sp.	s			heath		X						
Linum marginale	h	0.6		Wild flax			X			X		
Linum sp.	h	0.6	*	flax	X			X			X	
Lobelia gibbosa	h	0.4										X
Lomandra longifolia	h	1		Sedge,sagg	X	X	X	X	X	X	X	X
Lomatia tinctoria	s	1	e	Guitar plant							X	
Microseris lanceolata	h	0.3		Native dandelion						X		
Microtis sp.		1		Onion-orchid				X			X	
Olearia ramulosa	s	3		Twiggy daisy bush			X			X	X	
Olearia viscosa	s	2		Daisy bush							X	
Oxalis perenans	h								X	X		
Ozothamnus obcordatus	s	1.5					X			X		X
Ozothamnus scutellifolius	s	1	e				X				X	X
Parentucellia latifolia	h	0.3	*		X	X		X				
Petrorhagia nanteuilii	h	0.4	*		X			X				
Pimelea humilis	s	0.3		Common rice flower			X					
Plantago lanceolata	h	0.2	*	Ribwort	X	X		X	X		X	
Poa rodwayii	g	0.75		grass		X				X		
Poa sp.	g			grass		X	X		X	X		X
Podolepis jaceoides	h	0.6		daisy			X			X		
Pomaderris apetala	s/t	10		Dogwood							X	
Pomaderris elliptica	s/t	8	e	Yellow dogwood								X
Pteridium esculentum	f			Bracken					X	X	X	X
Ptilotus spathulatus	h	0.2		Pussy tails	X							
Pultenaea daphnoides	s	3		Native daphne								X
Pultenaea gunnii var. beacke	s	1.5	e									X
Pultenaea juniperina	s	2		Prickly beauty				X			X	X
Pultenaea pedunculata	s	0.3								X		X
Pultenaea prostrata	s	0.2								X		
Rosa rubiginosa	s	3	*	Briar-rose		X		X				
Schoenus apogon	h	0.4		sedge						X		
Senecio minimus	h	1.2				X					X	
Senecio sp.	h	0.5		groundsel	X	X	X	X	X	X	X	X
Sonchus sp.	h	1.2	*	Sow-thistle								X

Appendix VIII

Vegetation species occurring at each site

Scientific name	Type	max ht	Status	Common name	war	ros	nat	gor	mor	rok	mtr	mee
Stipa sp.	g	1.7		Spear Grass	X	X	X	X	X	X	X	X
Stylidium graminifolium	h	0.4		Trigger plant			X					
Taraxacum officinale	h	0.3	*	Common dandelion		X				X		
Tetratheca labillardierei	s	0.8										X
Themeda triandra	g	1.2		Kangaroo grass	X	X	X	X	X	X	X	X
Trifolium glomeratum	h	0.3	*	Clustered clover						X		
Verbascum virgatum	h	2	*	Twiggy mullein	X							
Vicia sp.	h		*								X	
Viola hederacea	h			Native violet						X		
Vittadinia gracilis	s	0.3		Woolly New Holland daisy	X					X	X	
Wahlenbergia sp.	h	0.5		Bluebell		X		X	X	X	X	X
Number of species of:	Total				war	ros	nat	gor	mor	rok	mtr	mee
Grasses	20				8	12	11	12	13	15	9	7
Herbs	52				15	12	10	17	10	25	15	10
Shrubs	43				4	10	14	13	9	16	18	21
Trees	9				3	3	8	4	6	5	4	6
Other	3				0	2	0	1	2	1	2	1
Endemic	7				0	0	3	0	1	2	3	6
Introduced	29				11	11	6	15	8	11	9	2
All plants	127				30	39	43	47	40	62	49	45