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The birds and habitat of Kings Park

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USE OF THESIS

The Use of Thesis statement is not included in this version of the thesis.

ABSTRACT

Kings Park is a large urban park in the centre of Perth with extensive areas of semi-natural bushland. The park is an important refuge for birds in the metropolitan area but is losing species through habitat disturbance. Understanding the way in which birds are related to their habitat helps to understand the effect of habitat disturbance on the bird community. The aim of this project was to generate guidelines which will aid in the management and conservation of birds in the park, through an understanding of the relationship of the birds to their habitat.

The avifauna and various habitat factors were sampled at selected points along the Mt Eliza escarpment and the Serventy and Recher transect in Kings Park. Notable differences in the abundance and composition of birds were found between the two study areas. Areas classified as disturbed on the Mt Eliza escarpment had a differing composition of bird species to areas classified as non-disturbed. Broad relationships were found to exist between patterns of the abundance and composition of the bird community and patterns in the habitat.

The results suggest that continued disturbance to the habitat of Kings Park will lead to an altered composition of the bird community, including a loss of further species. To conserve the existing species, careful management is required to minimise disturbance and restore degraded areas. Specific management guidelines that resulted from this study include maximising habitat diversity, minimising the spread of weeds, reducing weed cover, and reversing the decline of eucalypts within the park. Further study is necessary for the conservation of birds that are in decline or are rare in the park. The individual habitat factors and disturbance agents also need to be examined.

THESIS DECLARATION

I certify that this thesis does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any institution of higher education; and that to the best of my knowledge and belief it does not contain material previously published or written by another person except where due reference is made in the text.

Brad W. Cox
24th April 1998

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Chapter 1: Introduction

1.0 Overview

Kings Park is a large urban park of over 400 hectares and includes 267 hectares of semi-natural bushland. It is one of the few remaining remnants of bushland in central Perth and is highly significant in terms of its cultural and ecological value. The park was reserved in 1871 and extended to its current size in 1890 (Beard, 1967). From the time of its creation, the park has provided a unique place of relaxation and enjoyment for the people of Perth and its many tourists. The park is also a vital refuge for birds within the Perth urban environment. Its importance is indicated by the fact that it is listed on the Register of the National Estate under the Australian Heritage Act 1975 (Dixon *et al.*, 1995). The bushland was declared an A class reserve in 1900 and is included in the system six report for the Perth region (Department of Conservation and Environment, 1981).

The importance of Kings Park led the Commonwealth Government to establish the Kings Park Board in 1896 to ensure maintenance of its recreation, tourism and conservation values (Dixon *et al.*, 1995). In trying to achieve its objective of maintaining existing biota, the Kings Park and Botanic Garden has undertaken extensive studies. These studies are necessary to document and understand the parks' ecosystem and suggest how it can be maintained in such a high disturbance environment.

Research into the distribution and abundance of birds in Kings Park has been conducted since 1928 (Serventy, 1938; Recher and Serventy, 1991; Recher, 1997). This research has been carried out along a transect at the Western end of the park. Here the authors have illustrated that gradual changes to the habitat are affecting the bird community. They have shown that disturbance from sources such as logging, firewood removal, disease, insect attack and changed fire regimes have led to a changed composition in the bird community and a loss of several species (Recher, 1997).

The precise factors which determine the distribution and abundance of the birds in Kings Park, and the way in which disturbance is acting upon the bird community, are two areas which have not been addressed by these studies. It is the purpose of this study to closely examine the relationship of birds to their habitat, allowing the formulation of guidelines to reverse the current decline in the avifauna.

1.1 General Introduction

In trying to understand the factors influencing a particular community there are several questions which are often asked (Krebs, 1994). What enables a community to persist over time? What causes changes in communities? And what factors allow maximum diversity within a community? A community is defined by Krebs (1994, p574) as a 'group of populations of plants and animals in a given place.' Communities are important because they are not just the sum of a group of organisms, but the sum of the interactions between those organisms (Lobban and Schefter, 1997).

The complexity of communities has led ecologists to develop two general theories about communities to help explain how they are regulated and make them easier to understand. The first is the classical model of a community as a stable equilibrium in which the species richness remains constant over time (Chesson and Case, 1986). Under this theory communities are organised primarily through three biotic processes – competition, predation and mutualism (Krebs, 1994). It is assumed in this model that coexistence and persistence of species is only possible if these factors are operating to maintain a stable equilibrium. The other key assumptions of this model are that disturbance has minimal effects, that the environment is spatially and temporally homogeneous, and that migration is unimportant.

The second theory of non-equilibrium communities arose as an alternative to the equilibrium model on the grounds that many of its assumptions are not satisfied in natural systems. In a non-equilibrium community, processes other than biotic ones explain species persistence and it is not assumed that species are interactive. These mechanisms include variable and changing environments, density independent population dynamics and slow competitive displacement. Environmental perturbations are no longer assumed to be insignificant and variability in species densities is accepted as normal (Krebs, 1994).

In both equilibrium and non-equilibrium communities there are disruptive influences that can lead to instability in a community (DeAngelis and Waterhouse, 1987). Despite these influences, communities tend to persist through time. There are at least four mechanisms which enable this persistence and maintain species diversity. The first is increasing stabilising mechanisms, the second is compensatory mechanisms, the third is integration into the larger landscape and the fourth is an applied disturbance pattern (Chesson and Case, 1986). Disturbance is not always a process which disrupts communities. The intermediate disturbance hypothesis states that maximum diversity will be attained in a community at a level of disturbance that is not so severe as to cause species extinctions, but sufficient to reduce the effects of competitive exclusion (Krebs, 1994).

Having considered the processes of persistence, change and determination of diversity in a community the next logical question to ask is, 'what role does habitat and, in particular, vegetation, have to play in influencing these processes?' How is an animal related to its environment and how important are these relationships? The habitat of an animal refers to the range of conditions under which it can live and reproduce, including the resources which it uses for food and shelter (Lobban and Schefter, 1997). The way in which an animal is connected to its environment is fundamental to all studies that are conducted into plant and animal communities (Recher, 1985). Habitat is important to birds through the food, shelter and the materials it provides for survival and reproduction. Each particular bird species has resource requirements which determine whether it is able to survive in a particular area.

Kings Park, Perth, Western Australia, includes a community of birds which has been changed through disturbance to the habitat since the arrival of European settlers in Western Australia (Serventy, 1938; Main and Serventy 1957; Beard, 1967; Baird, 1977; Recher and Serventy, 1991; Dixon *et al.*, 1995). The change in habitat through processes such as logging, firewood removal, disease, insect attack and changed fire regimes have meant that the bushland is no longer a suitable habitat for certain birds (Recher and Serventy, 1991; Recher, 1997).

The birds of Kings park could not be classified as an equilibrium community. An equilibrim community is one in which historical effects and environmental perturbations play a small role (Chesson and Case, 1986). Instead, Kings Park is a disturbed, weakly interactive and non-equilibrium community, in which a long history of disturbance has had significant effects on the bird community and their environment. The fact that Kings Park is a non-equilibrium community does not mean that loss of a viable community is inevitable. In the case of Kings Park, the natural mechanisms of persistence that are referred to by DeAngelis and Waterhouse (1987) are not sufficient for long-term persistence of the community and maintenance of biological diversity. Effective management could alleviate some of the disturbance, aid in the preservation of particular species (especially those that are rare or endangered), and help maintain natural ecosystem processes so that the community persists in the longer term.

Ultimately, the most important question to ask, is *why* we try to understand the way in which communities operate and the factors influencing them. Usually the motivation for studying a community is not simply for ecological understanding, but to enable conservation and management of the environment in a certain area (Keast *et al.*, 1985). This study examines the community of birds in Kings Park and their associated habitat, to enable the conservation of birds in one of Perth's most significant urban bushland reserves. The aim of the study is to generate guidelines which will aid in the management and conservation of birds in the park through understanding the relationships with various habitat factors.

Successful conservation through management requires a detailed understanding of the way in which a particular ecosystem functions including the types of organisms present and the way in which they relate to their environment (Purves *et al.*, 1992). In Kings Park there is a lack of data on birds and an even greater gap in the knowledge of the factors which determine their abundance, distribution, and composition. This project aims to reduce this gap and thereby aid in the maintenance of a significant and valued set of species within the Perth urban environment.

1.2 Thesis outline and research approach

The relationship of birds and their habitat has been examined in environments throughout the world. Chapter two presents some of these studies and looks at the different approaches taken in each case. Kings Park is a unique ecosystem and contains a community of birds which has been heavily altered by disturbance. Chapter three gives a background to Kings Park, the bird community and some of the historical processes which have shaped the present avifauna. The method chosen to examine birds and their habitat was to count birds and sample the habitat at selected points in the park. This methodology is described in Chapter four. The major outcomes of the application of this method were to illustrate relationships between bird and habitat data and describe the effects of disturbance. These results are presented in Chapter five and then discussed along with management in Chapter six. The thesis ends with major conclusions and suggests directions for further research.

Chapter 2: Background on habitat and habitat disturbance

2.1 Introduction

The concept of how a community of birds is related to its environment is a question which has been frequently asked in ecological studies, particularly in studies which have been formulated for the management and conservation of natural areas (e.g., Gilmore, 1985; Loyn, 1985; Milledge and Recher, 1985; Shields *et al.*, 1985). Each of these studies considers birds and vegetation, and began in response to a perceived need for improved management and conservation of the avifauna.

The aim of this chapter is to review some of the many studies which have examined birds and their habitat and present the theoretical background which forms the basis of this study.

2.2 Review of the literature on birds and habitat

Habitat type, along with climate, geography and isolation, is a key factor which determines the composition and abundance of bird communities (Recher, 1985). Various works, on scales ranging from the local region to the bioregion, have demonstrated this. The reason for the extensive interest in understanding the role of habitat lies in its value in the management of bird populations and the understanding of the ecology of birds. At the local level, specific environmental factors can often be identified which can be used as tools for conserving or regulating the local population. At a regional level, habitat can be analysed to gain understanding of some of the reasons for regional changes in the abundance and diversity of birds.

When analysing bird populations, a key parameter is often species diversity. The scale of the study, from a single habitat to a region which includes multiple habitats will determine the type of bird diversity which can be analysed. Cody (1993) refers to alpha, beta and gamma diversity when discussing these scales of analysis. Alpha diversity equates to the within-habitat diversity, determined by the vegetation structure and other environmental variables (MacArthur, 1965). Beta diversity, or between-habitat diversity, is a product of the difference in species composition between habitats. It is a result of variation in the vegetation between the habitats and also from area effects, fragmentation and historical events. Gamma diversity is the overall regional diversity or the sum of the species from all habitats.

The factors operating to determine these diversities can be split into two broad categories. The first is floristics, or the types of plant species present, which are important because they determine the types of resources available and subsequently the particular guilds of bird species (see Loyn; 1985, Recher, 1985). The second is the structural features of the vegetation or physiognomy which is the way in which the vegetation is arranged both vertically and horizontally. It is significant because it determines the complexity, diversity and abundance of the resources available to birds (Gilmore, 1985). Disturbance involves changing the structure and/or floristics of the vegetation, thereby altering the resources and the number and types of guilds which can utilise the resources (Recher *et al.*, 1985).

Rotenberry (1985) showed, that on a regional scale, floristics tend to have the greatest influence. Within a particular habitat, however, structural components are usually of greater significance for bird species diversity. A number of workers have reported correlations between bird species and foliage height diversity, illustrating the significance of structure (MacArthur, 1964; Recher, 1969; Karr, 1971; Willson, 1974).

The approach taken to analyse data on birds and habitat has involved two main techniques. The first is to compare classifications and groupings of bird data to habitat data. The second is to attempt to correlate particular species or groups of birds with particular habitat variables. The strength of correlations with particular variables can indicate the importance of the variables to birds. For example, Leach and Recher (1993) found a high correlation between species richness and the volume of trees and the abundance of brigalow (*Acacia harpophylla*), but a low correlation with woody weeds.

Studies of birds and their habitat have often involved a simultaneous examination of foraging habits and analysis of guilds which feed on particular resources within a habitat

(Willson, 1974; Hino; 1985, Collins *et al.*, 1984). Particular guilds of birds such as insectivores, nectarivores and frugivores will have particular requirements in terms of the structure and floristics of the vegetation which they use as a source of food. This concept was examined in detail by Gilmore (1985, p 21) who tested the hypothesis that 'the abundance of co-existing insectivorous birds which utilize a particular foraging substrate is proportional to the quantities of that substrate.' Gilmore (1985) found that the abundance of insectivores was correlated with structure of the vegetation. Nectarivores and frugivores, by contrast, tend to respond to the floristic component of the vegetation since they rely upon flowers, nuts and/or seed of particular plant species (Terbough, 1985).

2.3 Birds and habitat disturbance

Many studies have investigated the influence of habitat disturbance on bird communities, particularly disturbance from fire and weed invasion (e.g., Hino, 1985; Brooker and Rowley, 1991; Recher and Serventy, 1991; Recher, 1997; Woinarski and Recher, 1997). Woinarski and Recher (1997) showed that despite the extensive study of birds and fire, there is still limited knowledge of the longer term effects of fire. Following a single fire, most communities tend to recover rapidly, although different bird species respond in different ways. Repeated fires are the most detrimental to birds and often lead to a loss of bird species from a particular area. Rowley and Brooker (1987) recommended a minimum period of ten years between fires for conservation of small heathland birds. In Kings Park, frequent fires have contributed to the loss of at least two species – the Black-capped Sittella and the Western Thornbill (Recher, 1997). Fires often lead to a temporary increase in the abundance of birds due to the development of a dense vegetation layer and other factors, such as an increase in the abundance of food. After the 1989 fire in Kings Park a dense layer of acacia shrubs developed, but there was no increase in the abundance of birds. This is possibly due to the poor nutrient status of the soil in Kings Park (Recher, 1997).

Weeds are a form of disturbance which are often associated with fire. A weed can be defined in various ways. An 'environmental' weed is a plant which has negative effects on the environment in which it is found (Humphries *et al.*, 1991). Weeds change the structure and composition of the vegetation at a particular site and can change the abundance or composition of the bird community at a site. This was illustrated by Williams and Karl (1996), who showed that endemic birds feed mainly on endemic plants and non-endemic birds feed on both endemic and non-endemic plants.

There are many problems involved with relating birds to habitat and understanding the impact of habitat disturbance. Terbough (1985) discusses some of these problems in relation to habitat selection in Amazonian rainforest. The first is the variety of mechanisms operating, such as the multiple requirements of food, shelter and nesting, that a habitat supplies. Terbough (1985) argues that these factors often act in parallel and confuse the relationship between birds and their habitat. The second problem is that there are variables other than vegetation which are influencing birds, such as competitors, predators and parasites. A study of birds and habitat must therefore account for these other factors and be cautious when drawing conclusions based simply on correlations in statistical data. Management for conservation of birds requires the recognition of, not only the importance of habitat, but also that birds will not respond to habitat in a uniform or predictable way.

Chapter 3: The Study Area and its Avifauna

3.0 Overview

Kings Park is heavily impacted upon by its urban surroundings (Harris and Scheltema, 1995). This chapter briefly presents Kings Park within its urban setting and describes the history of change that has occurred in its avifauna as a result of disturbance to the park's habitat. The individual study areas are examined along with their associated projects, namely the Escarpment Restoration Project (the Escarpment Project) and the Serventy and Recher transect study.

3.1 Background

The urban bushland of the Perth metropolitan area (Fig 3.1) is a significant habitat for birds in which the effects of floristics, structure and disturbance are still poorly understood. According to Harris and Scheltema (1995), the bushland provides a large and diverse habitat for 311 different bird species. The pressures of urban development mean that the bushland is continuously undergoing disturbance, which alters the habitat. This leads to changes in the species types and abundance of birds present and often a decline in species richness (total number of species) and total abundance. Two of the most significant forms of disturbance, which are discussed by Harris and Scheltema (1995), and apply both to Kings Park and urban bushland in general, are weed invasion and fire. Three hundred and fifty seven species of weeds have been identified in Perth, which most often enter bushland through human activities and disturbance. One problem with weeds is that they make the habitat more prone to fires (Wycherley, 1984).

Kings Park (Fig 3.2) has a long history of disturbance (Serventy, 1938; Main and Serventy 1957; Beard, 1967; Baird, 1977; Recher and Serventy, 1991, Dixon *et al.*, 1995). The change in habitat through processes such as logging, firewood removal, disease, insect attack and changed fire regimes have meant that the bushland is no longer a suitable habitat for certain birds (Recher and Serventy, 1991; Recher, 1997). The processes of disturbance have been operating in the park since the arrival of European settlers and recognition of the significance of these disturbances has not just occurred recently. Serventy (1938) identified that Kings Park was a disturbed environment when he began some of the earliest work on birds in the park in 1928. A changed composition in the avifauna of the park, was apparent as early as 1957, when several birds were identified as missing, including the Western Yellow Robin and Scarlet Robin (Western Australian Naturalists Club, 1957). The major changes in the parks habitat include a progressive loss of the eucalypt canopy and increasing ground cover (Beard, 1967). The eucalypts, that were once abundant in the park (jarrah, *Eucalyptus marginata,* marri, *E. calophylla*, and tuart, *E. gomphocephala*), are gradually being replaced by a lower canopy of sheoak (*Allocasuarina fraseriana*), firewood banksia (*Banksia menziesii*) and slender banksia (*B. attenuata)* (Bell *et al., 1992*). These changes have important impacts upon the bird community of the park.

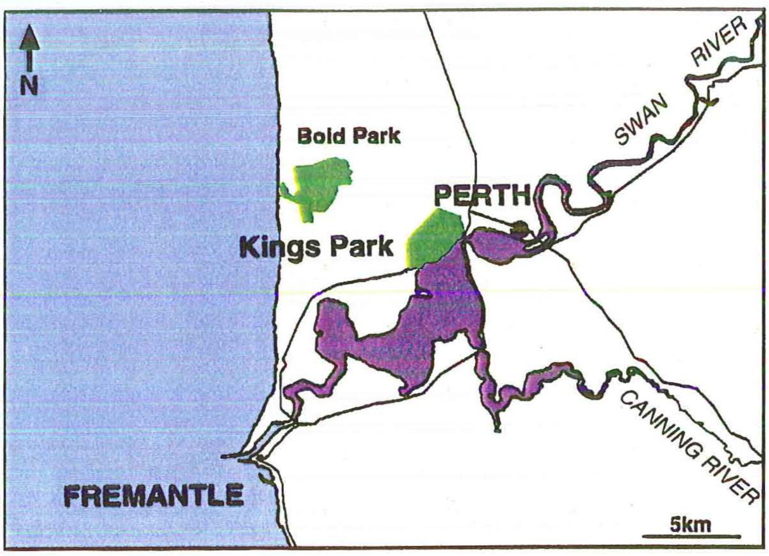

Figure 3.1; Kings Park in the Perth metropolitan area (Source: Dixon *et al.*, 1995).

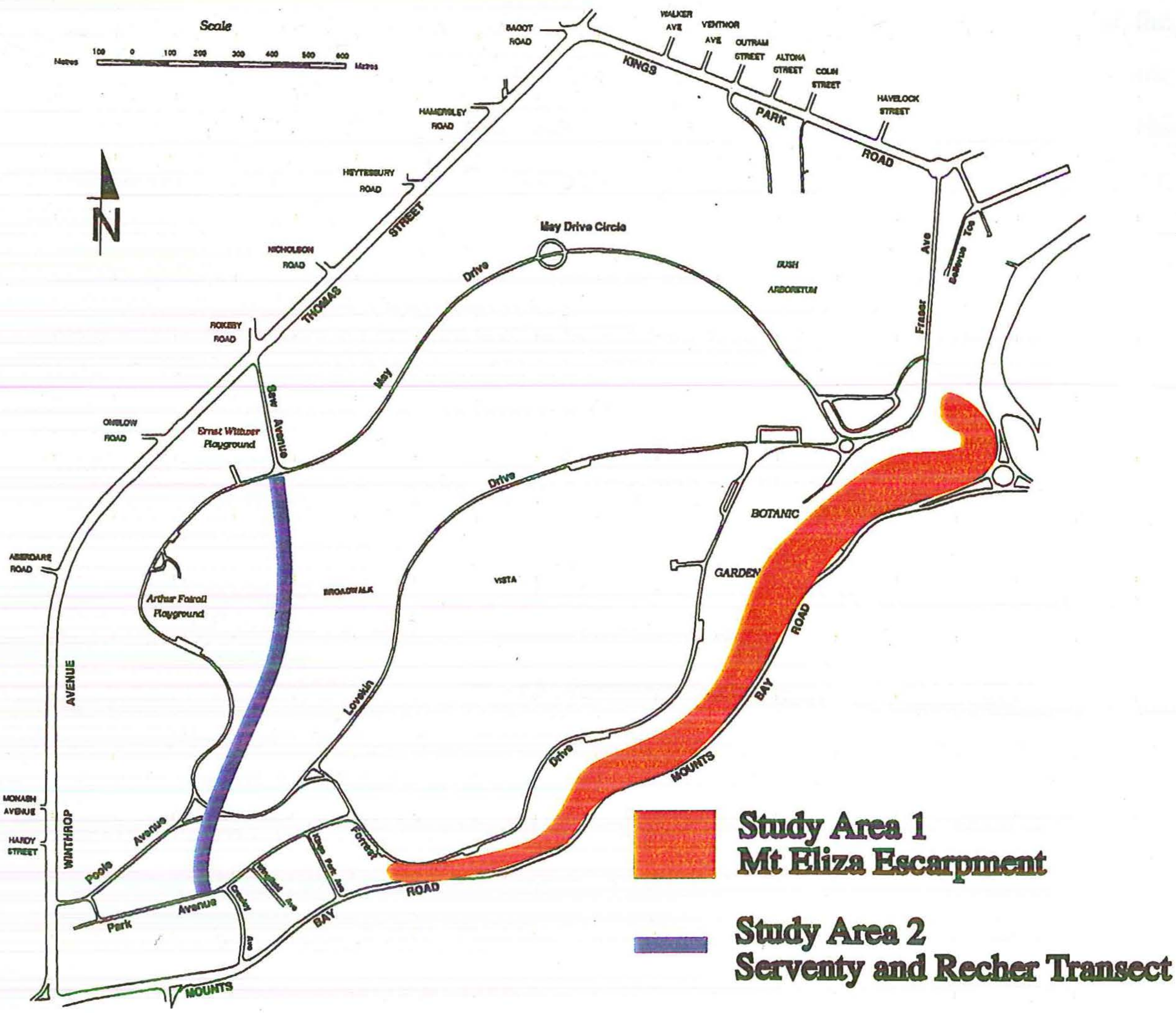

Fig 3.2; Kings Park and location of the two study areas (Source: Kings Park and Botanic Garden, 1997).

One of the major objectives of management, stated in the Kings Park Management Plan of 1995-2005, is to minimise disturbance to the Kings Park bushland and achieve long term sustainability (Dixon *et al.*, 1995). To achieve this objective, research is being conducted on a range of components of the park's biota and how it can be most effectively managed and restored.

The Escarpment Project, which is being conducted by the WMC Centre for Urban Bushland Management, is one such project which is focusing upon the Mt Eliza escarpment and on restoring the ecological integrity of the vegetation and its associated fauna. It was initiated in 1996, mainly due to the high level of degradation that is present along the escarpment, and also due to the significance and uniqueness of the escarpment ecosystem to Kings Park. Forms of disturbance on the escarpment include fire, weed invasion, feral animals and instability (Anon., 1998). Key factors in the restoration project include conservation and protection of significant species, eradication of key weed species and re-establishment of vegetation communities (Anon., 1997). The project involves sampling for vegetation in 33 plots, which have been positioned along the escarpment to represent the various vegetation types.

This project specifically considers birds as one significant group of fauna in need of protection along the escarpment (Fig 3.2, Plate 3.1). Sampling of the distribution and abundance of birds and the composition of the escarpment bird community was carried out at 15 plots, selected from 33 that were established in the Escarpment Project.

Plots were also established along the Serventy and Recher transect (the transect) at the western end of Kings Park (Fig 3.2, Plate 3.2). The transect was selected as a second study area because of the historical data available (H. Recher, unpub. data). Recent data collected since 1989 has been broken down into five sections along the transect (described by Recher, 1997). This has allowed comparison of the birds present in each section to the vegetation characteristics.

3.2 Plot selection and description

The 33 escarpment plots established by the WMC project are arranged in groups of three with one at the top, middle and bottom of the escarpment. The plots have an area of $100m^2$ (10m x 10m) and are spaced along a line of approximately 50-100m in length. Other plots on the Recher and Serventy transect were spaced at 100m intervals in a systematic sampling design. Designation of particular habitat types along the transect was not possible due to the lack of distinct boundaries between the different types of woodland.

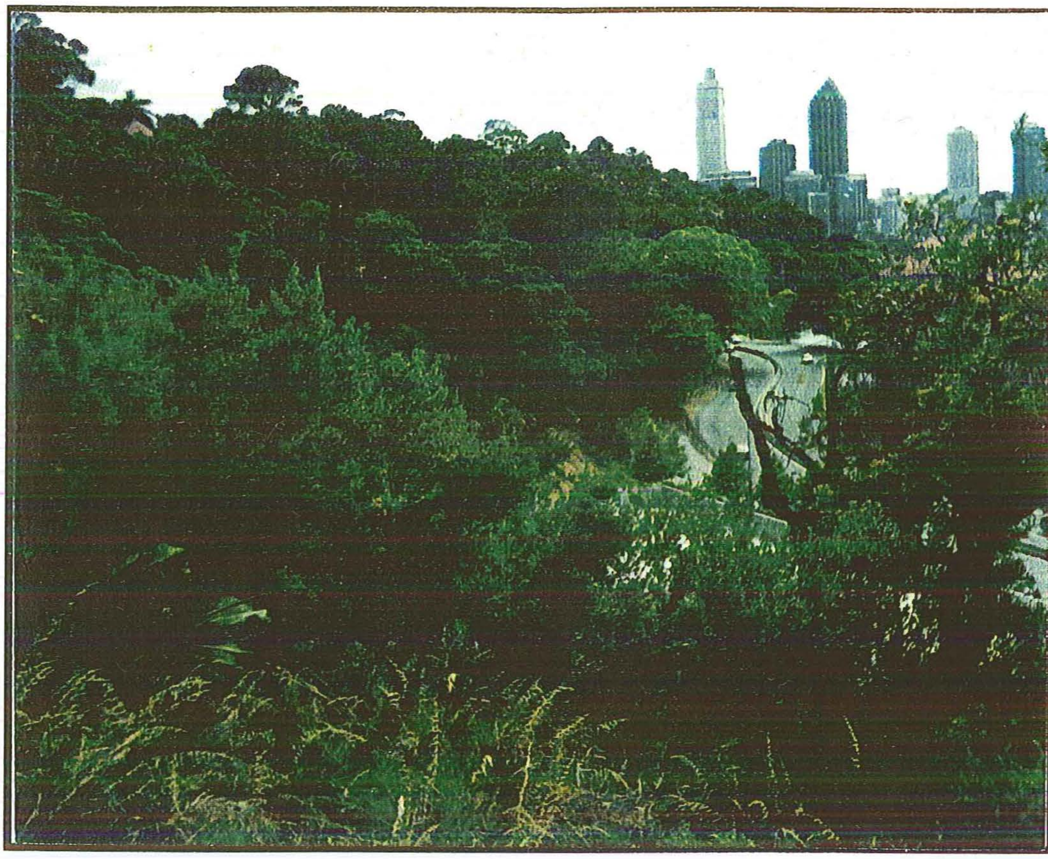

Plate 3.1; The Mt Eliza Escarpment study area.

Plate 3.2; The Serventy and Recher transect study area.

In selecting the 15 escarpment plots that were used for bird sampling, the middle plots were first exc' led to separate the sampling areas. Other plots were selected to include a high level of variation in vegetation type, structure, floristics and level of degradation. Vegetation type varies from woodland, to thick scrub (*Dryandra sessilis*), to low heathland. Some areas of the escarpment have a lower level of disturbance than others.

The first 6 plots of the Mt Eliza escarpment, which are at the southern end, are the least degraded. Plots 1 and 2 include heath shrubs *Hibbertia hypericoides, Acacia pulchella, Xanthorrhoea preissii* and *Anigozanthos manglesii* and canopy trees *Allocasuarina fraseriana* and *Banksia menziesii.* Plot 3, which is at the base of the escarpment, is dominated by dense *Dryandra sessilis.* Plots 4-6 are composed of taller species such as *D. sessilis* and *A. fraseriana,* some emergents such as tuart (*Eucalyptus gomphocephala*) and marri (*Eucalyptus calophylla)* and a sparser understorey. Plots 10-12 are described as transitional, from the least to the most degraded plots (Kathy Meney, pers. comm.). Plot 10, at the top of the escarpment includes a canopy of taller species such as *B. menziesii, A. fraseriana* and *D. sessilis* and a variety of understorey species. This contrasts to the plots 11 and 12, which are covered by dense *D. sessilis* and have extensive weed invasion. Plots 7 and 9 are composed of Marri (*E. calophylla*) woodland, which differs from the previous plots and is much closer to the vegetation of the Serventy and Recher transect and the remainder of the park.

Plots 22 and 24 are the most degraded of all the plots with weed invasion and erosion the main problems. The canopy includes conifer species over a limited understorey including *D. sessilis* and *Macrozamia riedlei.* Plots 19 and 21 are also quite degraded and undergoing restoration. The final group of plots (28, 29, 31) are at the northern most end of the Mt Eliza escarpment and include a variety of heath species which are invaded by weed species such as *Agave americans* and *Asparagus asparagoides.*

Plots on the Serventy and Recher transect were numbered from one at the southern end of the plot to ten at the northern end and spaced at one hundred metre intervals along the transect. The Serventy and Recher transect extends from the area of natural bushland into the Ernst Wittwer playground at the northern end but no plots were established in this section. A description of the variation in the vegetation along the transect is presented by Recher (1997).

Chapter 4: Methods

4.1 Introduction

Prior to this project, the only known sampling of birds which had been carried out in Kings Park was through mist netting by the Western Banders (Boyd Wykes, pers. comm.) and transects conducted by Serventy and Recher (Serventy, 1938; Serventy and Recher, 1991; Recher, 1997). The transect technique by Serventy and Recher involved walking along a designated path and recording all birds seen and heard, and their abundance along either side of the path to an unlimited distance. These data were incorporated in this project and allowed comparison to the vegetation characteristics recorded for each section of the transect. The other source of information, which this project utilises, is the database on the vegetation of the Mt Eliza Escarpment collected by the WMC Centre for Urban Bushland Management (K. Meney, unpub. data).

The first part of this chapter outlines the hypotheses used in this study and the reasons for their selection in the Kings Park environment. Application of the methods within the framework of the sites selected in both the woodland sites of the Serventy and Recher transect and the escarpment sites is then described followed by the means by which the final results were analysed.

4.2 Research hypotheses

This study utilised two main null hypotheses:

- that areas of differing habitat disturbance in Kings Park do not have bird communities that differ in species richness, abundance or composition.
- that the species types and abundance of birds present at a particular area are not related to features of the habitat.

4.3 Bird censusing

4.3.1 *Selection of methods*

This study utilises the interval point count techniques for sampling birds (also called the variable circular plot) (Franzreb, 1981). A transect technique was also used for comparison to the point technique.

Any bird census technique will involve drawbacks, including observer error, attraction and repulsion of birds, the movement of birds, the variable detectability of different species and the decreasing ability to detect birds with increasing distance from the observer (Recher, 1988). Selection of the appropriate method for a bird survey will depend on the objectives of the study, the habitat surveyed, the time available and the preferences of the observer (Pyke and Recher, 1984).

Selection of the appropriate technique for sampling of birds was made difficult in this study by some of the features of the escarpment environment in which the sampling took place. Sampling of birds has been conducted in other studies by methods including area searches, fixed width and unlimited distance transects, and spot counts (Pyke and Recher, 1984). Each of these techniques has advantages and disadvantages which must be weighed up within the context of the particular study. Ultimately the ideal method will provide reliable results, be practical in the field, and employ as few assumptions as possible (Franzreb, 1981).

The interval point count technique was selected for this study because it generated data which could easily be related to the vegetation for each plot, thus meeting the objectives of the study. The technique is only capable of generating relative data and not absolute densities of birds within an area. In this study, however, absolute data was not required. The second reason for selection of the interval point count technique is that it involves standing stationary at a point which is advantageous given the difficulty of movement up and down the escarpment and the damage that it can cause to the vegetation. Additionally, by standing at one point the problem of repelling birds is minimised and the point can be chosen so that it gives maximum visibility. The area being sampled is also very small, meaning that long transects or area searches would not be appropriate.

Finally, the method is simple and will minimise observer error, compar ' to other techniques.

4.3.2 *Application of the methods*

The interval point count involves standing stationary at a point for a fixed period of time and recording the birds observed and their distance and direction from the observer. Each point was censused for four minutes and birds were recorded within distance groupings of 0-5, 5-10, 10-20, 20-30 and >30 metres. Approximately one minute was allowed before sampling to minimise the effect of observer intrusion on the birds. The census time was chosen as a compromise between making sufficient observations and avoiding excessive re-counting of birds. This was determined by counting birds in one minute intervals until the cumulative number of bird species recorded reached equilibrium (Pyke and Recher, 1984). The distance groupings were based on suitability in the habitat sampled. Bias towards species which are most easily detected was minimised by careful observation and double counting was minimised by following the movement of birds.

All observations were made between 0600 and 1000 hours on fine days with light wind. Birds flying overhead were not recorded and an effort was made to avoid counting birds more than once. Sites were randomly sampled to account for the effect of time of day. At each point, the date, time, wind, cloud cover and temperature were also recorded. Temperature was recorded using a thermometer, cloud cover on a percentage scale of 0-100, and wind speed on a scale of 0-4. Any other pertinent observations were also noted.

4.3.3 *Bird sampling using a transect method*

Transect sampling of birds was conducted in the same areas as the point counts, to provide comparative data. The transects located cryptic bird species that were not recorded in the point counts and also species that were missed due to the restricted nature of the points.

The transect method used was the same as that used by Serventy and Recher (1991). This involved walking along the transect and recording the number of birds seen or heard to an unlimited distance. The transects were broken into sections and birds were recorded independently for each section to allow for analysis of differences along the transect. The transects were carried out at each of the locations of the survey plots - firstly along the Law Walk which runs along the escarpment and secondly along the Serventy and Recher transect.

4.4 Vegetation Sampling

4.4.1 *Sources of habitat data*

The Escarpment Project has generated a database on vegetation at each of the plots along the Mt Eliza Escarpment (K. Meney, unpub. data). This data was used along with the other information that was collected during habitat sampling. Habitat sampling was conducted on both the Mt Eliza Escarpment and the Serventy and Recher transect, through the selection and measurement of habitat variables.

4.4.2 *Procedure for collecting habitat data*

The first stage in collecting information on the habitat variables was to map the vegetation with a rough sketch of the key vegetation types and features of the plot. Aspect of the slope was measured with a compass. A rating was compiled for weeds in total, for veldt grass (*Ehrharta calycina*) and for bridal creeper (*Asparagus asparagoides*), on a scale of 0-5, where 0 = no weeds; 1 = <5% weeds; 2 = 5-9% weeds; 3 = 10-19% weeds; 4 = 20-50% weeds and 5 = >50% weeds. Disturbance was rated qualitatively on a scale of 0-5. This was an overall rating to indicate the disturbance to a particular site including weed invasion, fire and erosion.

At each plot, vegetation was broken down into its major structural layers. Each of these layers was then described according to the cover of dominant species, average height, and total cover (see Kent and Coker, 1992). By summing the cover of each layer, the total percent vegetation cover could by determined (Willson, 1974). Also recorded were a rating to indicate structural diversity (0-5), based on the heterogeneity of the height of the layers, and a rating to indicate the degree of clumping in the vegetation (0-5) over the plot area.

Trees were described by the distance to, and height of, the two nearest trees in each quarter of each plot, taken from a central point for a total of eight measurements. Foliage height diversity was calculated using a diversity index as is described in MacArthur and MacArthur (1961). This was based on the number of touches of the vegetation on a vertical pole, in the height intervals of 0-0.3m, 0.3-1m, 1-2m, 2-3m and 3-5m at 30 points in each plot.

4.5 Selection and description of variables

The selection of appropriate variables for the study (Table 4.1) was based upon allowing comparisons between plots according to birds and finding relationships to habitat variables. The habitat variables selected were all considered important in determining the distribution, abundance of birds and composition of the bird community. The large number of variables examined (30) was justified by the uncertainty as to which would prove significant in the final analysis.

Table 4.1; The variables used in this project for description of birds and habitat.

Variable	Unit/Scale	Means of Measurement
1. Birds		
Abundance of Individual species	Number	Pooled counts of 22 species for spring and summer separately within a 30m plot
Total Abundance	Number	Total number of individuals for each plot in each season
Richness	Number	Total number of species for each plot in each season
Diversity – H'	Index	Shannon Wiener Diversity Index (Zar, 1984)
Evenness – J'	Index	Evenness Index (Zar, 1984)
2. Habitat (21 variables)		
Aspect	Bearing	Bearing of 0 to 360 degrees measured using a compass
Tree distance	m	Average distance to the nearest 2 trees in each quarter of the 30m plot

Trees average height	m	Average height of the two nearest trees in each quarter of the 30m plot
Weed rating	1 to 5	0= almost no weeds; 1 = <5%; 2 = 5-9%; 3 = 10-19%; 4 = 20-50%; 5 = >50%
Bridal creeper rating	1 to 5	As above
Veldt grass rating	1 to 5	As above
Disturbance rating	1 to 5	As above
Number of layers	Number	Estimate and count the number of layers in the vegetation
Structural diversity rating	Number	A measure of the number of layers plus heterogeneity in layers. 0 = I layer; 2 = 2 layers even; 3 = 2 layers uneven; 4 = 3 layers even; 5 = 3 layers uneven; 5 = 4 layers even; 6 = 4 layers uneven
Clumping rating	Number	A measure of heterogeneity in the vegetation. 0 = no clumping; 1 = minimal clumping; 2 = some clumping; 3 = strong clumping; 4 = highly clumped
Pcvc (percent vegetation cover)	%	Percent vegetation cover - sum of the cover of each layer
Average height of each layer (4 variables)	m	Average height of each layer defined according to the habitat classification system of Elton and Miller (1954) in Kent and Coker (1992).
% cover of each layer (4 variables)	%	Estimated over the entire plot for each layer in the vegetation.
Burn index	Number	0= no evidence of fire; 1 = some evidence(trees black, some dead); 2 = strong evidence (regrowth, dead trees, black stems)
FHD index (foliage height diversity index)	Number	Shannon Wiener diversity index for the number of foliage touches in each height interval.
3. WMC Centre for Urban Bushland Management Variables (9 variables)		
Plant species abundance	Number	Number of individuals of all species in each plot
Plant species richness	Number	Number of species in each plot
Plant species diversity - H'	Index	Shannon Wiener diversity index
Plant species evenness – J'	Index	Evenness index
% cover native vegetation – average	%	Estimated in 3 1x1 plots
% cover weed vegetation – average	%	Estimated in 3 1x1 plots
% bare ground – average	%	Estimated in 3 1x1 plots
Average maximum vegetation height	m	Estimated in 3 1x1 plots
% Weed cover – Quantitative	%	Estimated in 3 1x1 plots

Table 4.1 (cont'd); The variables used for description of birds and habitat.

4.6 Research design and site selection

4.6.1 *Research components and timing*

This study was designed to examine birds and habitat in two separate areas, the Mt Eliza Escarpment and the Serventy and Recher transect. Fifteen plots were selected along the Mt Eliza Escarpment (out of 33 established by the WMC Centre for Urban Bushland Management) and ten were established along the Serventy and Recher transect. Bird sampling was conducted along the Mt Eliza Escarpment six times for each of the escarpment plots in spring (between the 11th of September 1997 and the 14th of November 1997) and summer (between the 26th of November 1997 and the 10th of December 1997, and between the 7th of January 1998 and the 20th of January 1998). The Serventy and Recher transect plots were sampled six times in summer only (between the 26th of November 1997 and the 10th of December 1997 and between the 7th of January 1998 and the 20th of January 1998). Habitat was sampled at both locations during the spring and summer bird censusing.

4.6.2 *Plot layout*

Birds were sampled at the same location as the vegetation. In the case of the escarpment this referred to the plots established by the WMC Centre of Urban Bushland Management and in the case of the Serventy and Recher transect to newly established plots. Where possible, the point was in the centre of the plot but was moved slightly if necessary to obtain the best vantage point for observation.

4.7 Data analysis

Analysis involved the following components:

- Pooling of results for each point for the different times
- Chi-square analysis to test the significance of variation in a variable against plot
- Classification and ordination of the points according to birds
- Classification and ordination of the points according to habitat
- Correlations between bird and habitat variables.

The type of data involved in the analysis varied from nominal (e.g. presence/absence of particular species) to ratio (e.g. abundance of species present). Non-parametric techniques were used after considering the distribution of the data. The computer packages PATN (after Belbin, 1994) and SPSS For Windows were used to perform the analysis. The significance level for all tests was set at 0.05.

Data for birds was first pooled for each season and location to provide sufficient numbers of analysis. After the pooling, a bird was classified as abundant if it had a pooled abundance of greater than fifteen.

Comparisons of the bird populations were based not only on abundance of particular species but on total abundance, species richness, species diversity (H', Shannon Wiener, Zar, 1984) and species evenness (J', Zar, 1984). Comparisons were made at various levels - between individual plots, between groups of plots and between vegetation types.

Multivariate analysis using PATN was first used to calculate similarity indices, and then to classify and ordinate the data according to birds and vegetation. The Bray-Curtis Association Index was used to calculate the similarity indices. The bird classification utilised FUSE and Flexible UPGMA linking. The vegetation classification used the Gower Metric Association index, FUSE and Flexible UPGMA linking. The multivariate analysis of vegetation was performed three times using different variables. The first classification and ordination was based on the variables of percent vegetation cover, and foliage height diversity. For the second classification and ordination, the percent vegetation cover was first log transformed. The third classification and ordination used the variables of tree height, tree distance and percent vegetation cover, which were all log transformed, and foliage height diversity. DEND was used to derive dendograms for each classification. Ordination was performed using SSH

Chapter 5: Results

5.0 Overview

The results have been broken down into five sections. The first describes an ordination performed in the Escarpment Project which examines the level of disturbance along the escarpment and provides a basis for the other sections of the results. The second section presents figures which illustrate how the bird and habitat variables vary over the range of plots. The purpose of presenting these data is to compare the patterns of change between plots, among both birds and vegetation. Differences between the plots in the woodland, along the escarpment and seasonal differences are also considered. The third section presents and compares the classifications and ordinations that were performed on the bird and habitat data. The fourth section outlines the results of the correlations which were performed between bird and habitat variables. Finally, the chapter presents some additional analysis using bird data from the Serventy and Recher transect (H. Recher, unpub. data) and results of the alternative transect method used in this project.

5.1 Escarpment Project ordination

Principal co-ordinates analysis of the 33 escarpment plots (K. Meney, unpub. data) showed a division between 'disturbed' sites at the north-east of the escarpment and 'undisturbed' sites at the south-western end of the escarpment, with some exceptions. For the 15 escarpment plots used in this project, plots 1 to 18 and 29, 32 were undisturbed plots and plots 19 to 24 were disturbance plots. The variables determined to be responsible for this division and used in the final ordination were percent native vegetation, percent weed cover, and percent bare ground. Disturbed sites were characterized as having high proportions of weed cover, while undisturbed sites had higher proportions of native vegetation and bare ground.

A significant negative correlation was found between percent native vegetation and percent weeds (r =-0.532, df =31, $p<0.05$), and between percent native vegetation and the quantitative weed rating (r=-0.537, df=31, $p<0.05$) (K. Meney, unpub. data). This suggests that the three variables are inter-linked and are good indicators of disturbance.

5.2 Bird and Habitat variables

5.2.1 *Bird variables*

A total of 22 species of birds were recorded in this study, seven of which were classed as abundant, meaning that they were recorded with an abundance of greater than fifteen at any particular location and season (Table 5.1).

A matrix was produced which showed the abundance of each bird at each plot for each of the seasons (Appendix 1).

Chi-square analysis was performed separately for both the escarpment and transect plots, for the bird variables (Appendix 2). The purpose of the analysis was to highlight bird species showing a statistical difference in abundance on each of the plots (Table 5.2).

Table 5.1; List of species recorded in this study (scientific names from Pizzey and Knight, 1997) and the location where they were recorded (X = present at a location and season; XX = present in abundance >15; XXX = present in an abundance >30; N = Nectarivore guild; I = Insectivore guild, O = Other guild).

Common Name	**Scientific Name**	**Present Scarp**		**Present Transect**
		Spring	**Summer**	**Summer**
Australian Magpie (O)	*Gymnorhina tibicen*			X
Australian Raven (O)	*Corvus coronoides*	X	X	
Brown Honeyeater (N)	*Lichmera indistincta*	XXX	XXX	XXX
Galah (O)	*Cacatua roseicapilla*		X	
Laughing Kookaburra (O)	*Dacelo novaeguineae*	X	X	X
Laughing Turtledove (O)	*Streptopelia senegalensis*	XX	X	X
Little Wattlebird (N)	*Anthochaera chrysoptera*			
Port Lincoln Parrot (O)	*Barnardius zonarius*	X	X	X
Rainbow Bee-eater (I)	*Merops ornatus*	X	X	X
Rainbow Lorikeet (O)	*Trichoglossus haematodus*	XX	XXX	XX
Red Wattlebird (N)	*Anthochaera carunculata*	XXX	XXX	XXX
Rufous Whistler (I)	*Pachycephala rufiventris*		X	X
Spotted Turtledove (O)	*Streptopelia chinensis*		X	
Silver-eye (N)	*Zosterops lateralis*	X	XX	XX
Singing Honeyeater (N)	*Lichenostomus virescens*	XXX	XXX	X
Striated Pardalote (I)	*Pardalotus striatus*			X
Weebill (I)	*Smicrornis brevirostris*		X	X
Western Spinebill (N)	*Acanthorhynchus superciliosus*			X
White-cheeked Honeyeater (N)	*Phylidonyris nigra*	XXX	X	X
Western Warbler (I)	*Gerygone fusca*			X
White-tailed Black Cockatoo (O)	*Calyptorhynchus latirostris*		X	
Yellow Rumped Thornbill (I)	*Acanthiza chrysorrhoa*			X
Total Number of Species	**22**	**11**	**16**	**17**

Table 5.2; Birds which showed a significant χ^2 value for the Mt Eliza Escarpment and the Serventy and Recher transect.

Mt Eliza Escarpment				**Serventy and Recher transect**	
Spring		**Summer**		**Summer**	
Species	**p value**	**Species**	**p value**	**Species**	**p value**
Australian Raven	0.001	Australian Raven	0.001	Australian Magpie	0.025
Laughing Kookaburra	0.001	Galah	0.001	Laughing Kookaburra	0.025
Silver-eye	0.001	Port Lincoln Parrot	0.005	Rainbow Bee-eater	0.025
Port Lincoln Parrot	0.001	Rainbow Bee-eater	0.005	Rainbow Lorikeet	0.025
Rainbow Bee-eater	0.001	Rainbow Lorikeet	0.05	Rufous Whistler	0.01
Rainbow Lorikeet	0.001	Rufous Whistler	0.001	White-cheeked Honeyeater	0.025
		Spotted Dove	0.005	Western Spinebill	0.025
		Weebill	0.001		
		White-cheeked Honeyeater	0.001		
		White-tailed Black Cockatoo	0.001		

The summary variables for birds were not tested using χ^2. Patterns in these variables between seasons are evident from histograms. For the plots classified as undisturbed by the WMC ordination, the total abundance of birds was higher in spring with the exceptions of plots 1 and 29 (Fig 5.1). For the disturbed escarpment plots 19, 22 and 24, the abundance of birds was higher in summer. The highest abundance of birds was found in escarpment plots 4, 29 and 32, and the transect plots 2, 7 and 8. The escarpment plots 4, 10, 29 and 32 were all plots with high densities of *Dryandra sessilis* (pers. obs.). Escarpment plot 10 was a plot located high on the escarpment near the botanic gardens. Low abundance was typical of plots found near the bottom of the escarpment. This was particularly prevalent in summer. Few bird species was found in the escarpment plots 3, 7 and 18 (Fig 5.2). High richness was found in escarpment plots 4, 19 (a disturbed plot) and 32 on the escarpment and in plots 2, 6 and 8 along the Serventy and Recher transect.

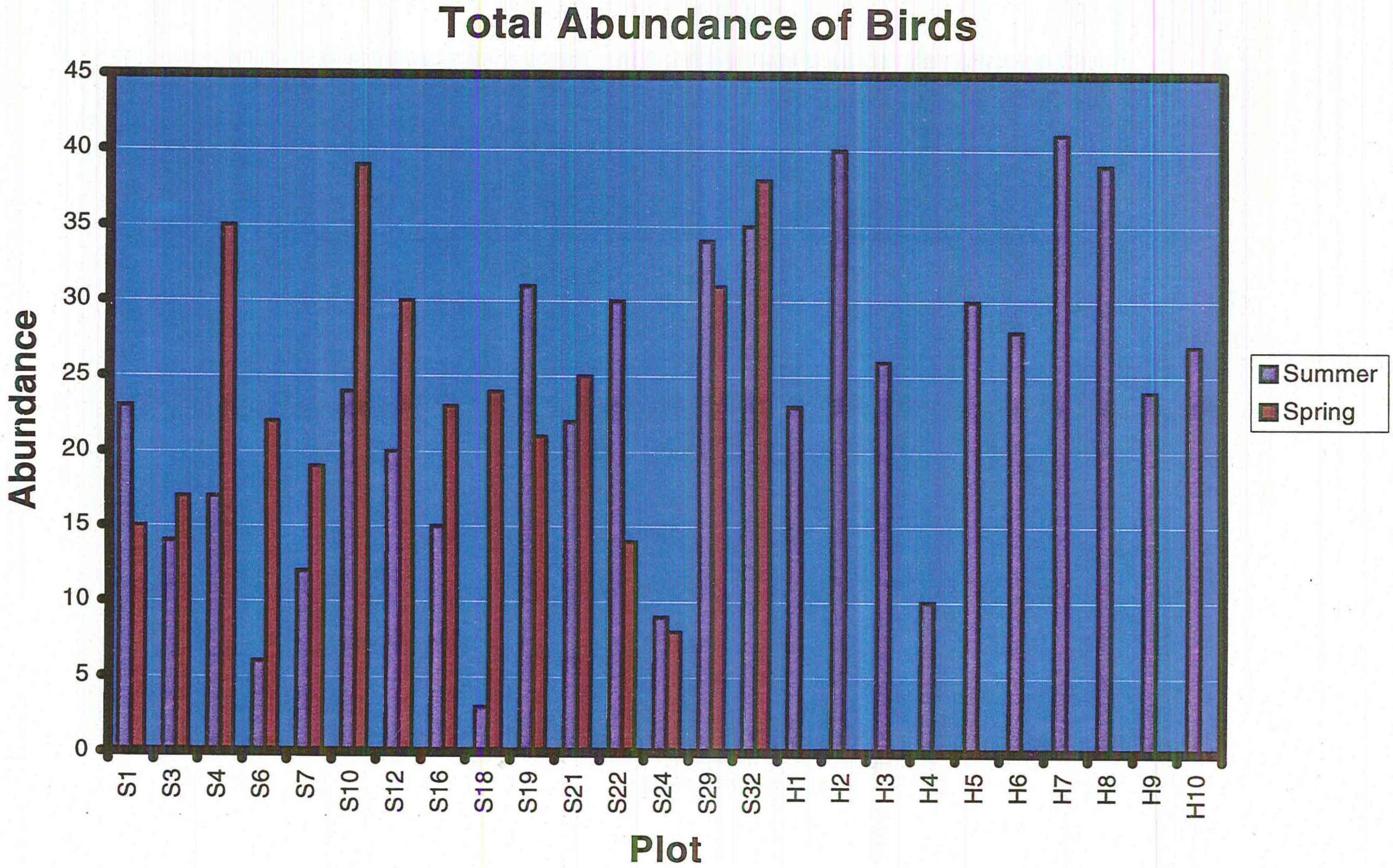

Fig 5.1; The total abundance of birds at each of the sites in spring and summer. Plots prefixed by an S indicate escarpment plots and plots prefixed by a H indicate plots along the Serventy and Recher transect.

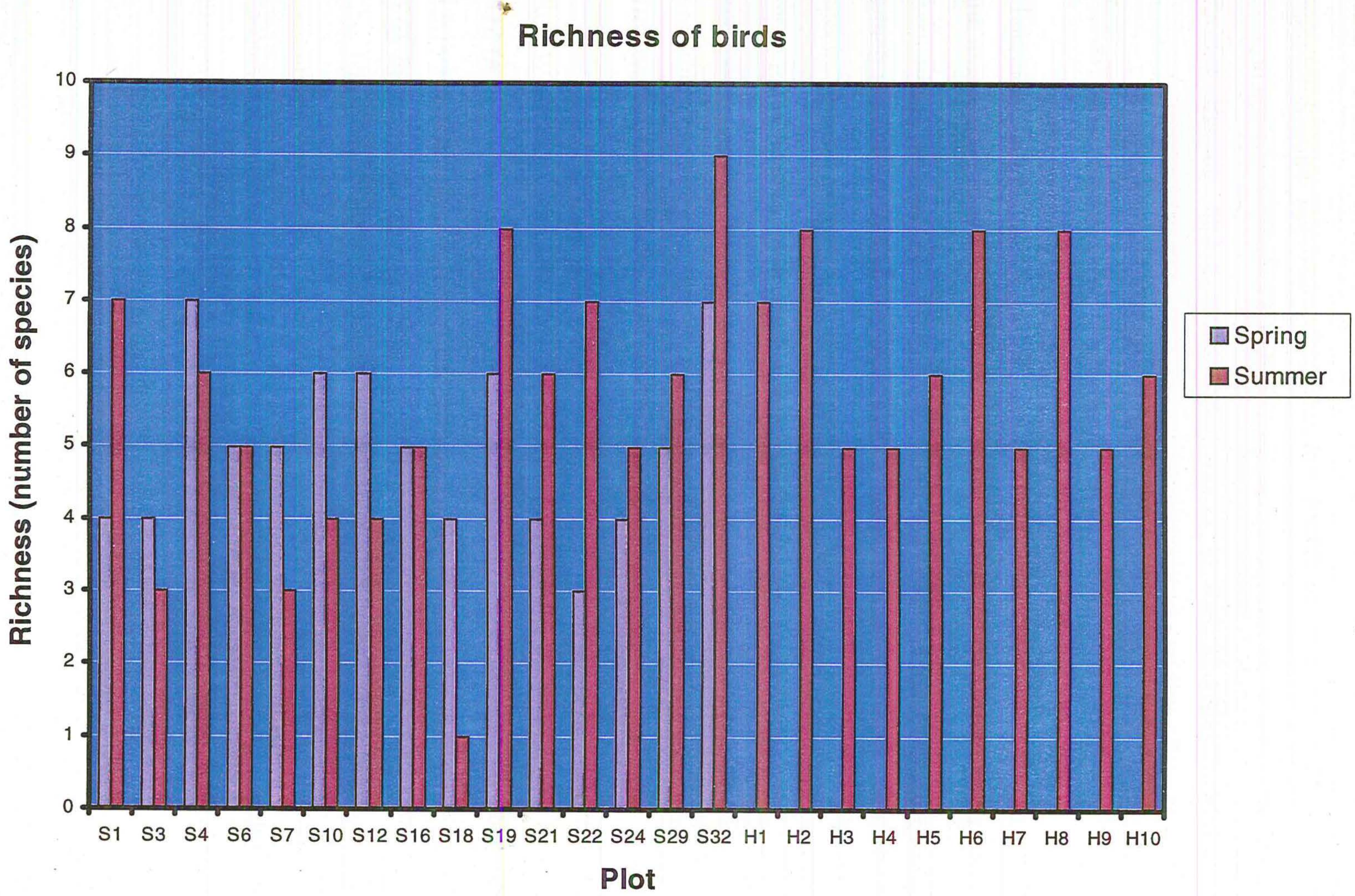

Fig 5.2; The species richness of birds at each of the sites in spring and summer. Plots prefixed by an S indicate escarpment plots and plots prefixed by a H indicate plots along the Serventy and Recher transect.

The remaining plots along the Serventy and Recher transect also had a consistently high richness as compared to the escarpment plots. There appears to be a shift in the richness from a higher richness in spring on escarpment plots 3 to 18 (which are heath plots supporting high numbers of nectivorous birds) to a higher richness in summer on escarpment plots 19 to 32 (which lack nectar supporting vegetation). Patterns of bird species diversity and evenness were similar to that of richness (Fig 5.3). There is particularly low diversity in escarpment plots 3, 7 to 18 and two of the transect plots, 3 and 7.

Histograms are presented for the five most abundant species of birds. Brown honeyeaters, the most common of all birds recorded, were variable in their distribution among sites (Fig 5.4). Brown Honeyeaters were abundant on escarpment plots 10 to 18, 29 and 32, all of which are sites with high densities of *Dryandra sessilis* and other high nectar producing species. Brown Honeyeaters were uncommon on escarpment plots 19 to 24 which lack these plant species. They were also less abundant during summer when most plants have stopped flowering. Abundances were high for some transect plots even for summer. This is probably because of the flowering eucalyptus (*Eucalyptus sp.*) which the Brown Honeyeaters were seen to feed on (pers. obs.).

Red Wattlebirds were abundant on escarpment plots 19, 21 and 22 (all disturbance plots), S32 (a plot with a high density of *D. sessilis*) and the transect plot 6 (Fig 5.5). Rainbow Lorikeets were most common in summer, particularly on escarpment plots 19 to 32 (Fig 5.6). In spring, Rainbow Lorikeets were found on different plots. It was only on escarpment plot 19 that they were found in both seasons. Singing Honeyeaters were common on the escarpment disturbance plots 19, 21 and 22 (Fig 5.7). White-cheeked Honeyeaters were a species not common on disturbance plots (with the exception of 21), but common where there was dense *D. sessilis* stands on escarpment plots 1 to 6, 12 to 18, 29 and 32 (Fig 5.8).

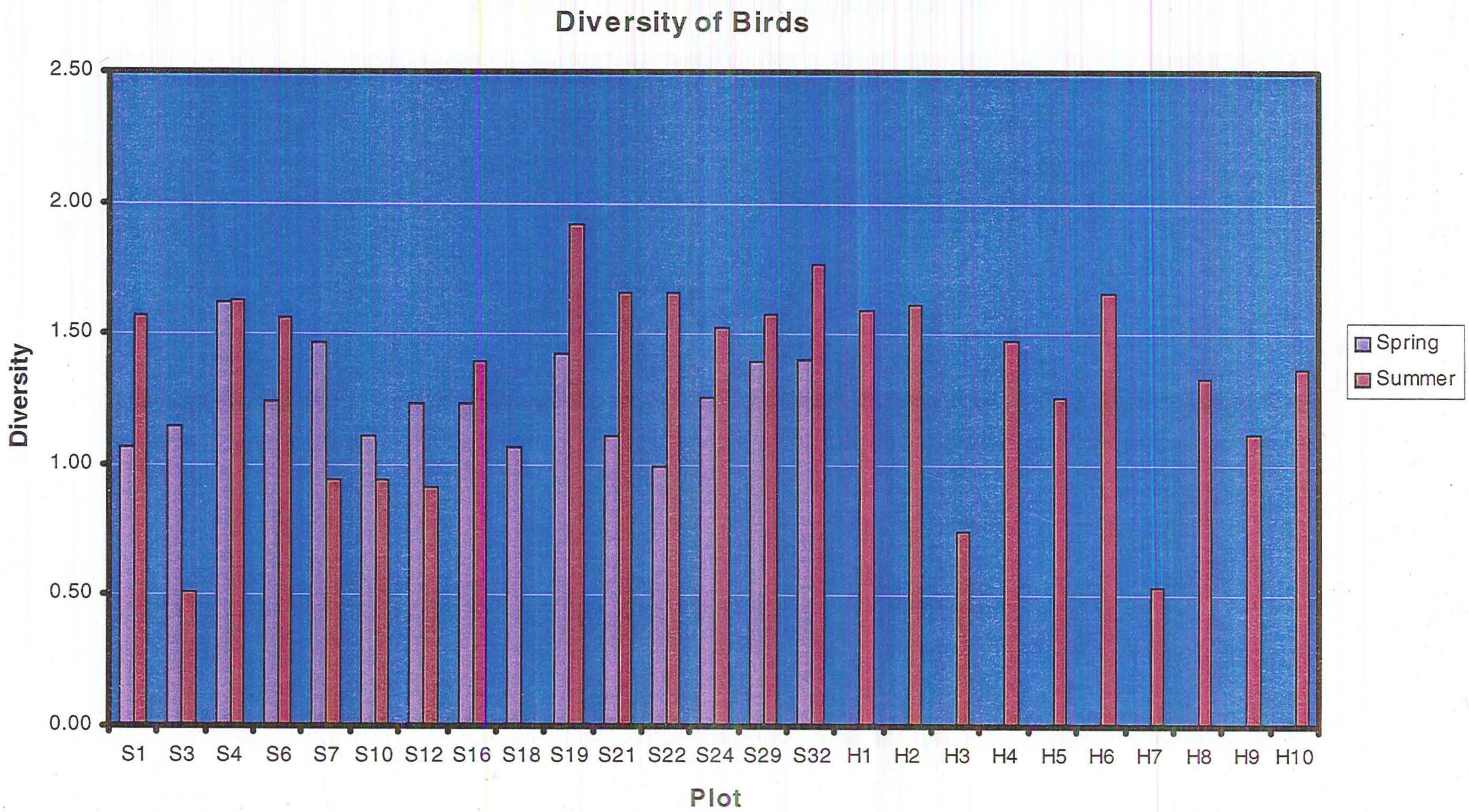

Fig 5.3; The species diversity of birds at each of the sites in spring and summer. Plots prefixed by an S indicate escarpment plots and plots prefixed by a H indicate plots along the Serventy and Recher transect.

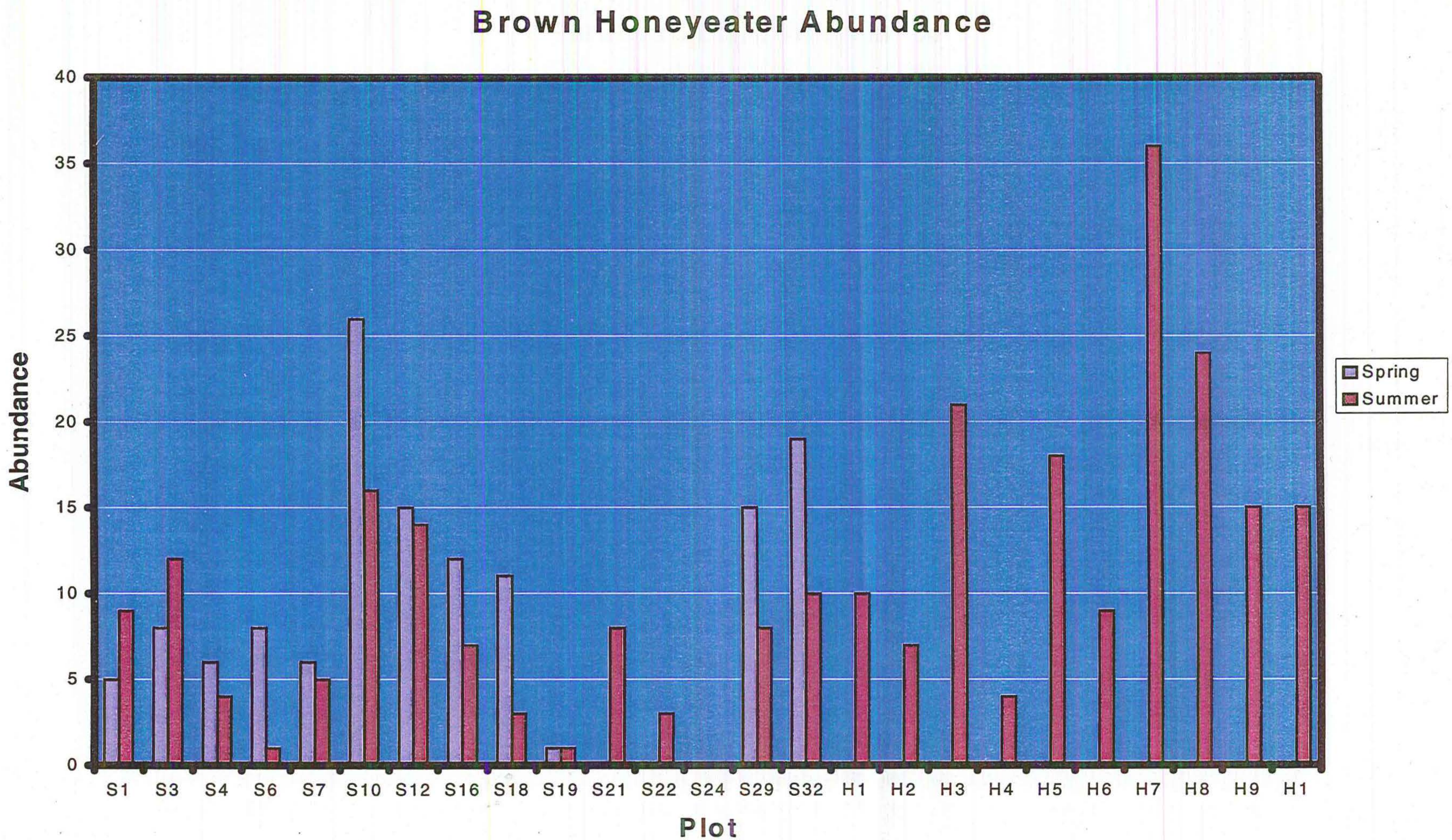

Fig 5.4; The abundance of Brown Honeyeaters at each of the sites in spring and summer. Plots prefixed by an S indicate escarpment plots and plots prefixed by a H indicate plots along the Serventy and Recher transect.

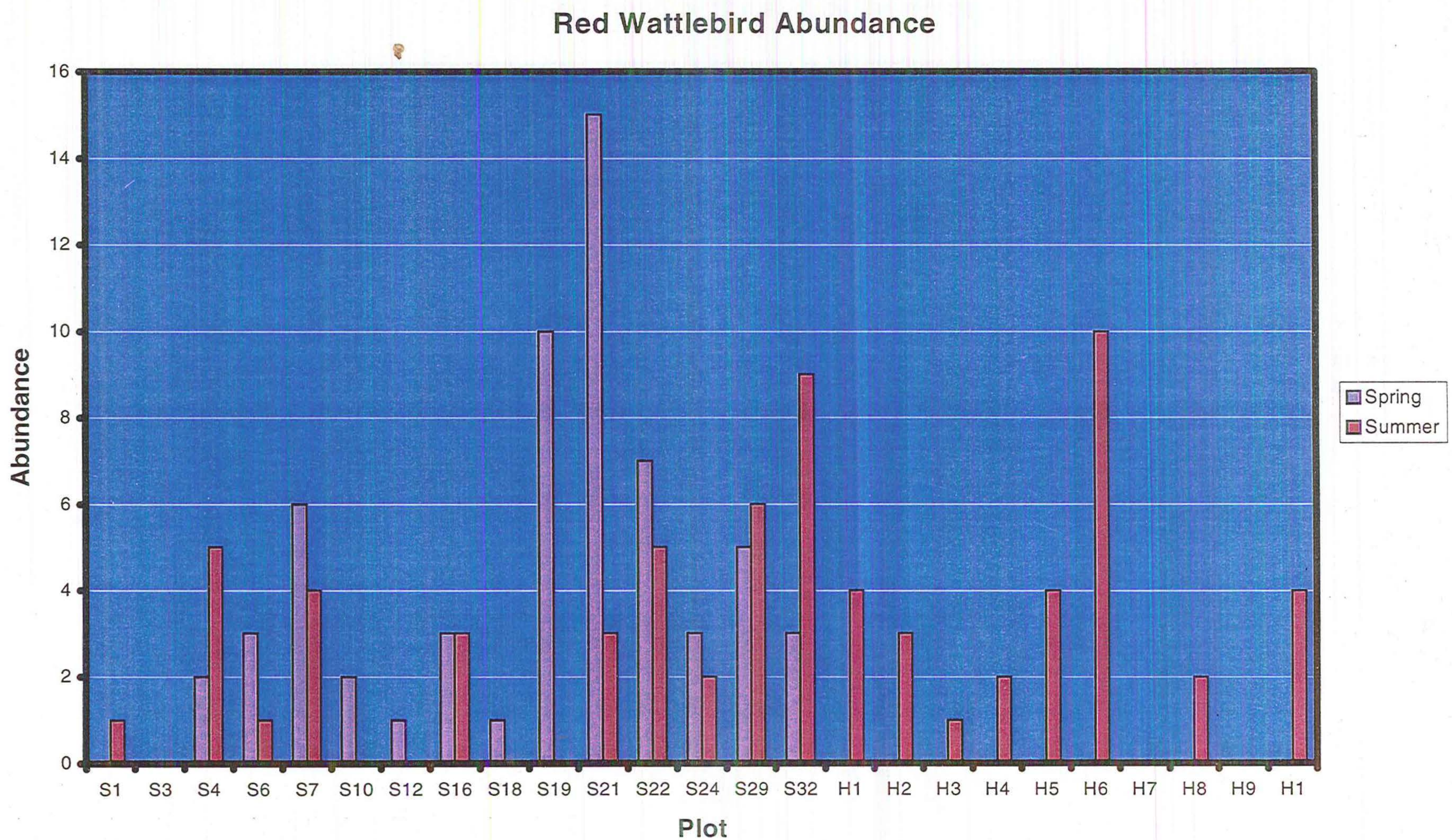

Fig 5.5; The abundance of Red Wattlebirds at each of the sites in spring and summer. Plots prefixed by an S indicate escarpment plots and plots prefixed by a H indicate plots along the Serventy and Recher transect.

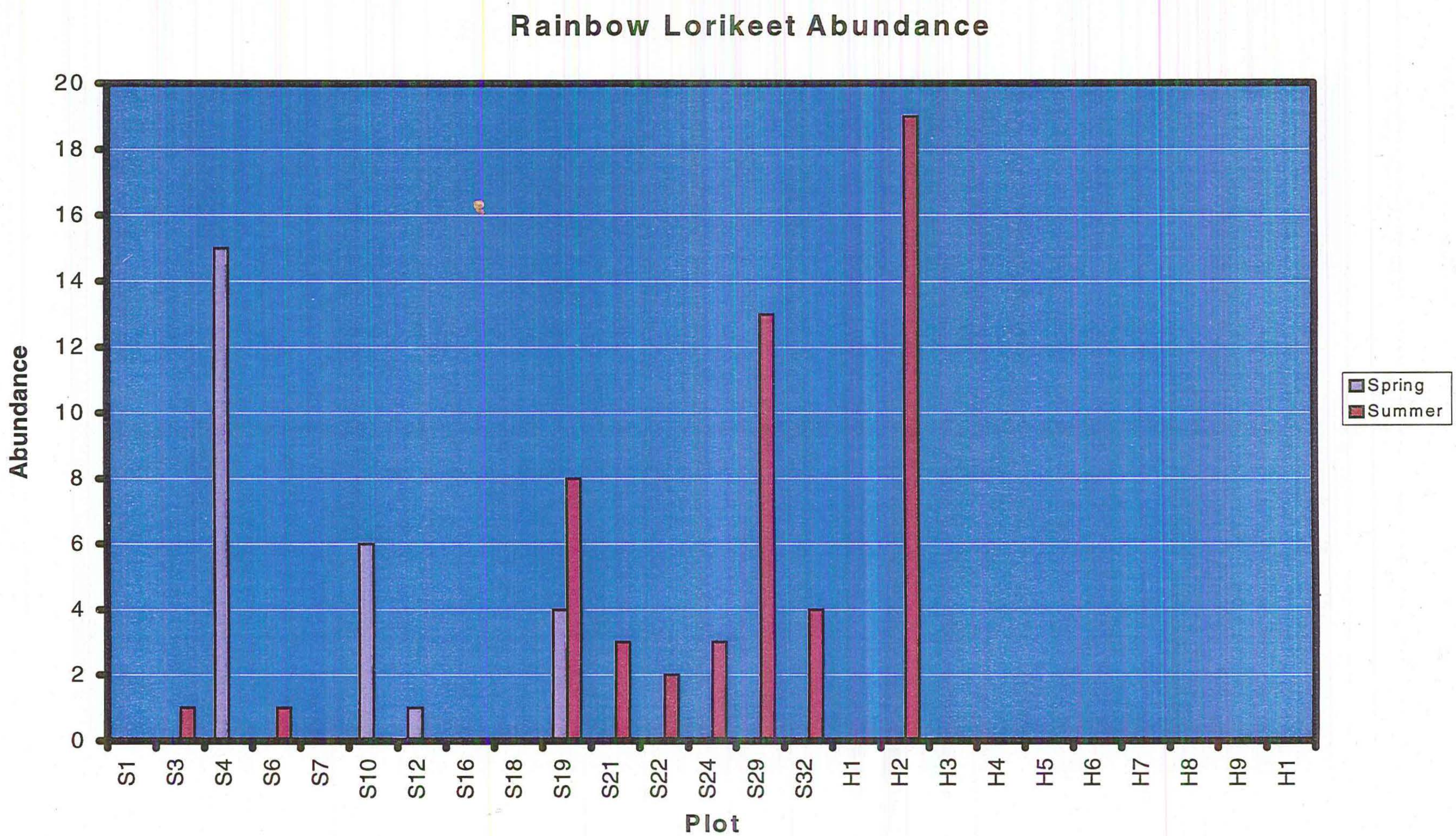

Fig 5.6; The abundance of Rainbow Lorikeets at each of the sites in spring and summer. Plots prefixed by an S indicate escarpment plots and plots prefixed by a H indicate plots along the Serventy and Recher transect.

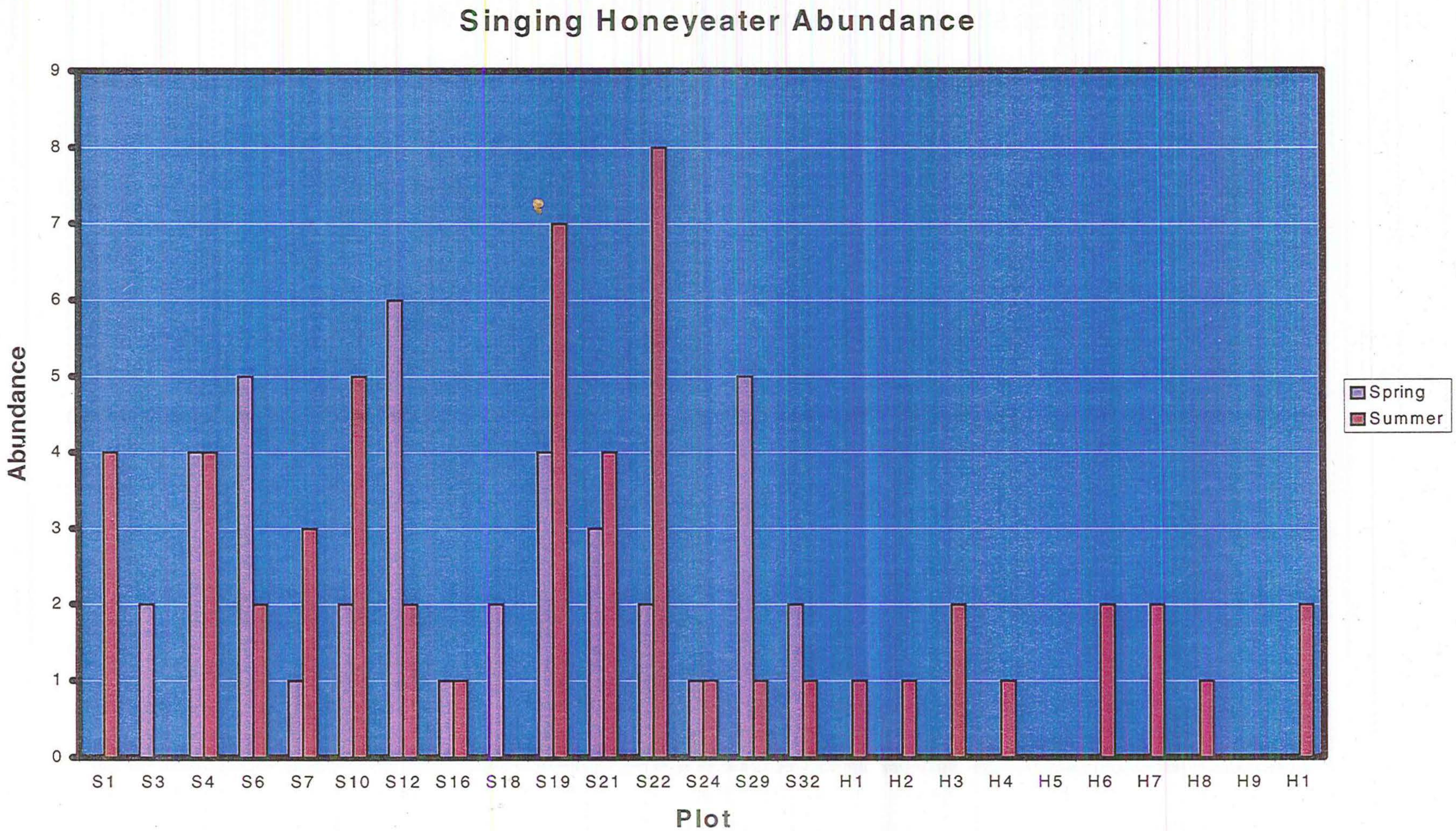

Fig 5.7; The abundance of Singing Honeyeaters at each of the sites in spring and summer. Plots prefixed by an S indicate escarpment plots and plots prefixed by a H indicate plots along the Serventy and Recher transect.

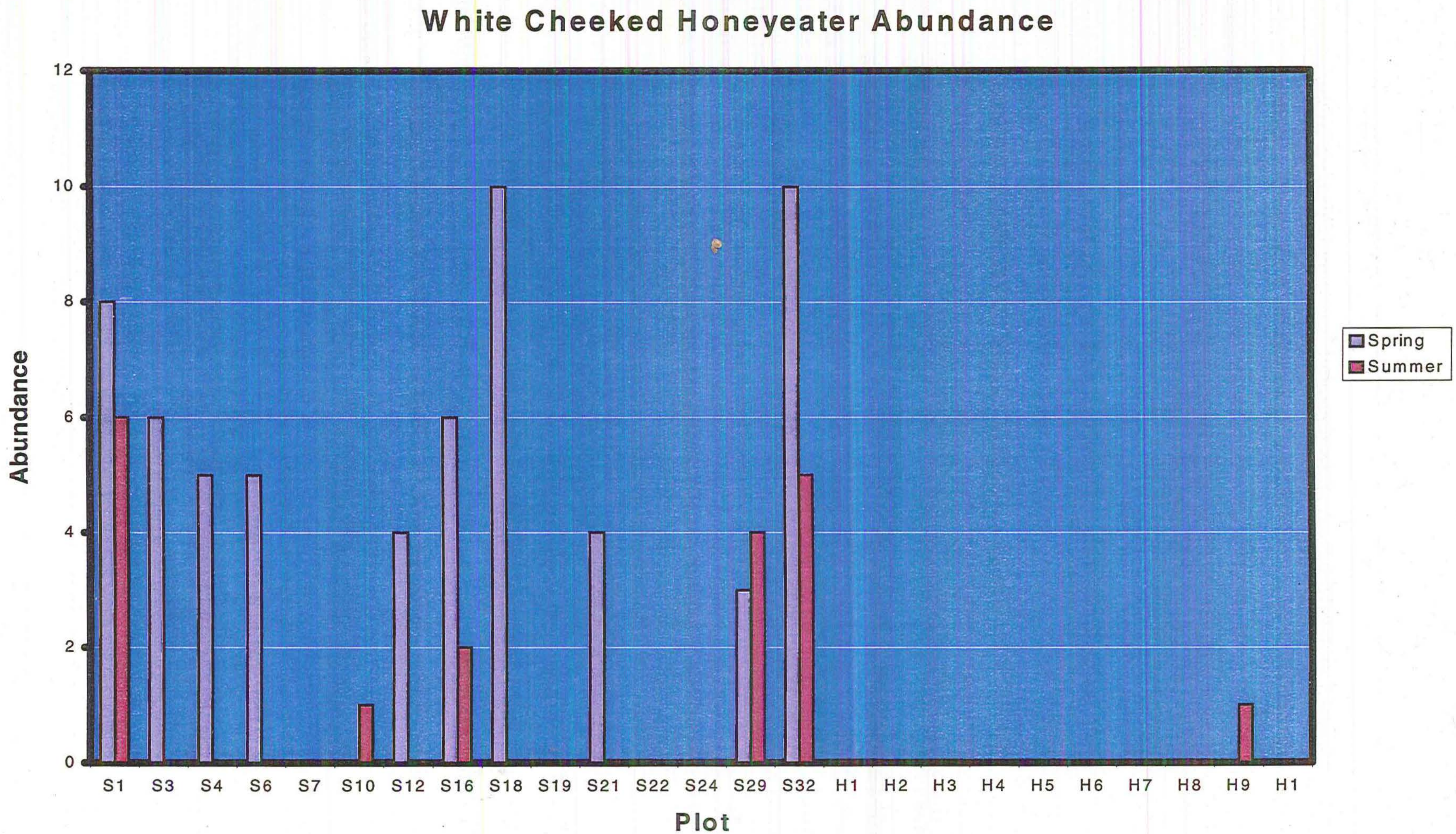

Fig 5.8; The abundance of White Cheeked Honeyeaters at each of the sites in spring and summer. Plots prefixed by an S indicate escarpment plots and plots prefixed by a H indicate plots along the Serventy and Recher transect.

5.2.2 *Comparison of disturbed and undisturbed plots*

Comparison of disturbed and non-disturbed plots on the Mt Eliza Escarpment did not reveal distinct differences in total abundance, species richness, species diversity or species evenness (Table 5.3). However, differences were evident between the abundance of particular feeding guilds of bird species. Non-disturbed plots had higher abundances of the nectarivores (nectar feeders) and insectivores (insect feeders). Disturbed plots had higher abundances of birds classified as 'other', which included frugivores (seed eaters).

Table 5.3; Comparison of mean values for bird summary variables and abundances of guilds on the Mt Eliza Escarpment disturbed plots (19, 21, 22, 24) and non-disturbed plots (1, 3, 4, 6, 7, 10, 12, 16, 18, 29, 32).

FACTOR	DISTURBED		NON-DISTURBED	
	SPRING	SUMMER	SPRING	SUMMER
Total Abundance	17	22.75	26.64	18.36
Species Richness	8	11	11	12
Species Diversity	1.19	0.78	1.3	0.75
Species Evenness	0.85	0.74	0.8	0.69
Abundances of Feeding Guilds of Bird Species:				
Nectarivores	12.5	15.5	22.73	15.36
Insectivores	0	0.25	0.18	2.45
Other	4.5	7.25	3.73	0.55

Ranked abundances of the birds recorded for disturbed and undisturbed sites indicated differences in the types of birds found at each area (Table 5.4). Brown Honeyeaters were ranked highest for non-disturbed plots, but lower for disturbed plots, especially in spring. Red Wattlebirds ranked highly for both seasons on the disturbed plots, but low on the non-disturbed plots. Singing Honeyeaters and Rainbow Lorikeets ranked highly in summer for the disturbed plots compared to the non-disturbed plots in summer.

Table 5.4; Comparison of ranked abundances of species on Mt Eliza Escarpment disturbed plots (19, 21, 22, 24) and non-disturbed plots (1, 3, 4, 6, 7, 10, 12, 16, 18, 29, 32).

BIRD SPECIES	DISTURBED		NON-DISTURBED	
	SPRING	SUMMER	SPRING	SUMMER
Australian Raven	0	0.05	0.02	0
Brown Honeyeater	0.03	0.6	1	1
Galah	0	0.1	0	0
Laughing Kookaburra	0.03	0	0	0
Laughing Turtledove	0.34	0.25	0.09	0.06
Little Wattlebird	0	0	0.04	0
Port Lincoln Parrot	0.03	0.30	0.03	0.02
Rainbow Bee-eater	0	0.05	0.02	0.02
Rainbow Lorikeet	0.11	0.70	0.17	0.22
Red Wattlebird	1	0.90	0.2	0.33
Rufous Whistler	0	0	0	0.02
Spotted Dove	0	0	0	0.01
Silver-eye	0	0.60	0.01	0.13
Singing Honeyeater	0.29	1	0.23	0.26
Weebill	0	0	0	0.02
White-cheeked Honeyeater	0.11	0	0.44	0.20
White tailed black cockatoo	0	0.05	0	0

5.2.3 *Comparison of escarpment plots to transect plots and spring to summer seasons*

The total abundance of birds, species richness, diversity and evenness was similar between the Mt Eliza Escarpment and the Serventy and Recher transect (Table 5.5). The major difference between these two areas was the greater abundance of insectivores on the Serventy and Recher transect. The abundance of nectarivores and other guilds was similar for the escarpment and the transect.

Table 5.5; Comparison of mean values for bird summary variables and abundances of guilds for the Mt Eliza Escarpment and the Serventy and Recher transect in the summer season.

FACTOR	MT ELIZA ESCARPMENT	SERVENTY AND RECHER TRANSECT
Total Abundance	19.63	26.60
Species Richness	15	15
Species Diversity	0.76	1.11
Species Evenness	0.70	0.66
Abundances of Feeding Guilds of Bird Species:		
Nectarivores	15.40	21.9
Insectivores	0.47	3
Other	3.77	3.6

Ranked abundances of the bird communities at the Mt Eliza Escarpment and the Serventy and Recher transect showed that there were differences in composition for the two areas (Table 5.6). The Brown Honeyeater ranked highest for both the escarpment and the transect. The Red Wattlebird ranked second for both areas but its abundance, relative to the abundance of Brown Honeyeaters, was lower for the transect. In comparison to other species, the Brown Honeyeater was more dominant on the transect than on the escarpment. The Singing Honeyeater, Rainbow Lorikeet and Silver-eye had high relative ratings for the escarpment compared to the transect.

Table 5.6; Comparison of ranked abundances of species for the Mt Eliza Escarpment and the Serventy and Recher transect.

BIRD SPECIES	MT ELIZA ESCARPMENT	SERVENTY AND RECHER TRANSECT
Australian Magpie	0	0.01
Australian Raven	0.01	0
Brown Honeyeater	1	1
Galah	0.02	0
Laughing Turtledove	0.1	0.01
Port Lincoln Parrot	0.08	0.04
Rainbow Bee-eater	0.03	0
Rainbow Lorikeet	0.33	0.12
Red Wattlebird	0.47	0.19
Rufous Whistler	0.02	0.03
Spotted Dove	0.01	0
Silver-eye	0.23	0.10
Singing Honeyeater	0.43	0.08
Striated Pardalote	0	0.01
Weebill	0.02	0.08
Western Spinebill	0	0.01
White-cheeked Honeyeater	0.18	0.01
Western Warbler	0	0.03
White tailed black cockatoo	0.01	0
Yellow Rumped Thornbill	0	0.08

A comparison of the spring to summer bird data revealed a higher abundance of birds during spring for the Mt Eliza Escarpment, probably a response to the greater number of flowering plants (Table 5.7). Species richness was lower in the spring than summer, while species diversity was higher and species evenness was similar in both seasons. More nectarivores were recorded during the spring, due to the greater nectar availability. More insectivores were recorded during the summer and the abundance of other birds was constant.

Table 5.7; Comparison of mean values for bird summary variables and abundances of guilds for the Mt Eliza Escarpment in the Spring and Summer seasons.

FACTOR	SPRING	SUMMER
Total Abundance	24.07	19.63
Species Richness	12	15
Species Diversity	1.27	0.76
Species Evenness	0.81	0.70
Abundances of Feeding Guilds of Bird Species:		
Nectarivores	20	15.40
Insectivores	0.13	0.47
Other	3.93	3.77

5.2.4 *Habitat variables*

Initial analysis identified seven habitat variables that seemed to be having notable effects on the bird community (Table 5.8).

Table 5.8; Important variables that were used in the analysis

SAMPLED VARIABLE	WMC VARIABLE
Percent vegetation cover	Percent weed cover
Foliage height diversity	Percent native vegetation cover
Tree distance	Percent bare ground
Tree height	

There were recognisable differences in the habitat data, both between study areas, and individual plots. The average height of trees is uniform over all plots except escarpment plots 6 and 19 where particularly tall trees were found, and escarpment plots 12 and 18 where there were no trees present (Fig 5.9). A greater average distance to trees indicates a lower density (Fig 5.10). High average distances were found specifically in escarpment plots 3 and 16 (*Dryandra sessilis* and heath sites respectively) and escarpment plots 19 to 32. The woodland plots along the Serventy and Recher transect had a greater density.

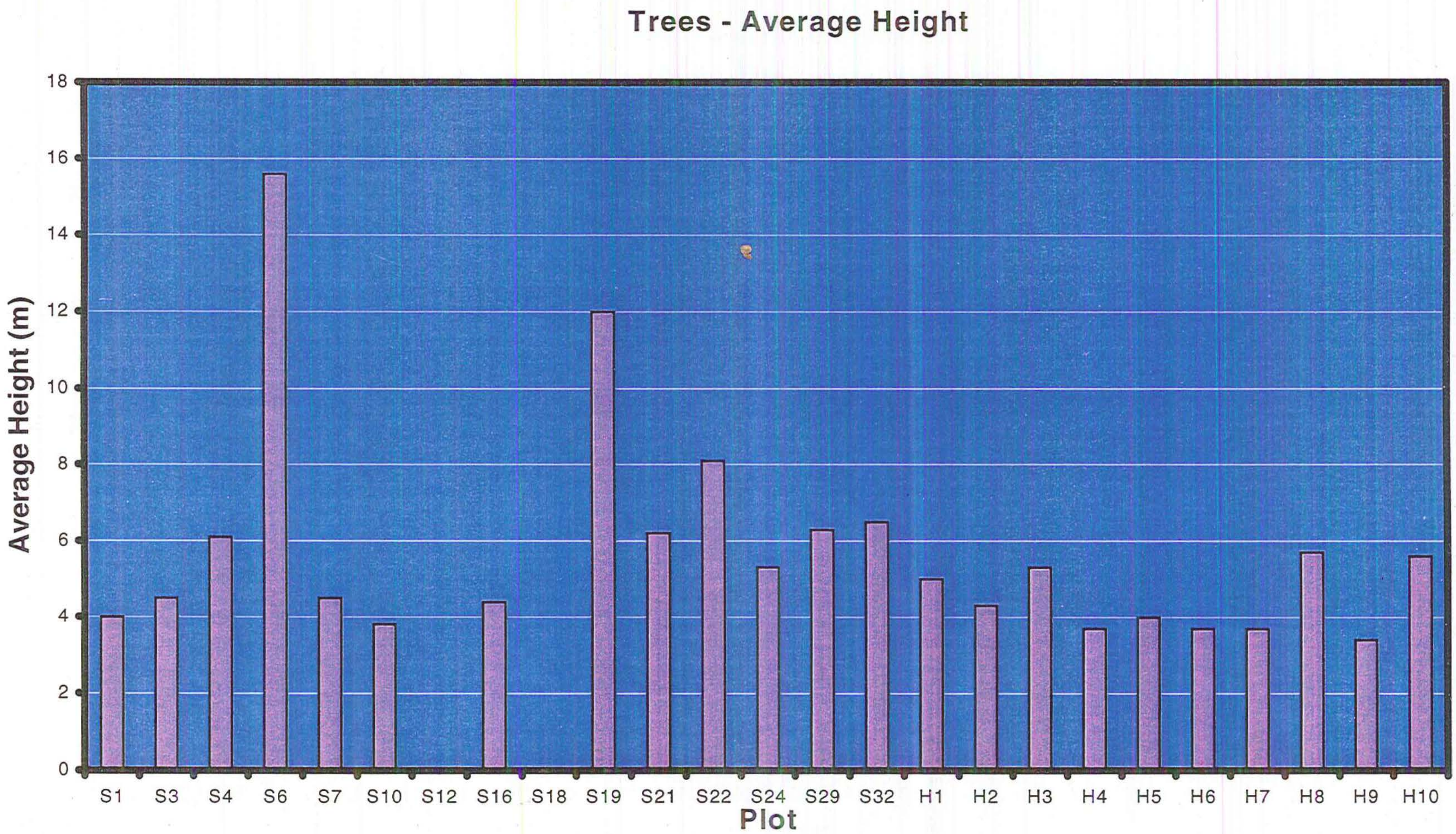

Fig 5.9; The average height of trees at each of the sites. Plots prefixed by an S indicate escarpment plots and plots prefixed by a H indicate plots along the Serventy and Recher transect.

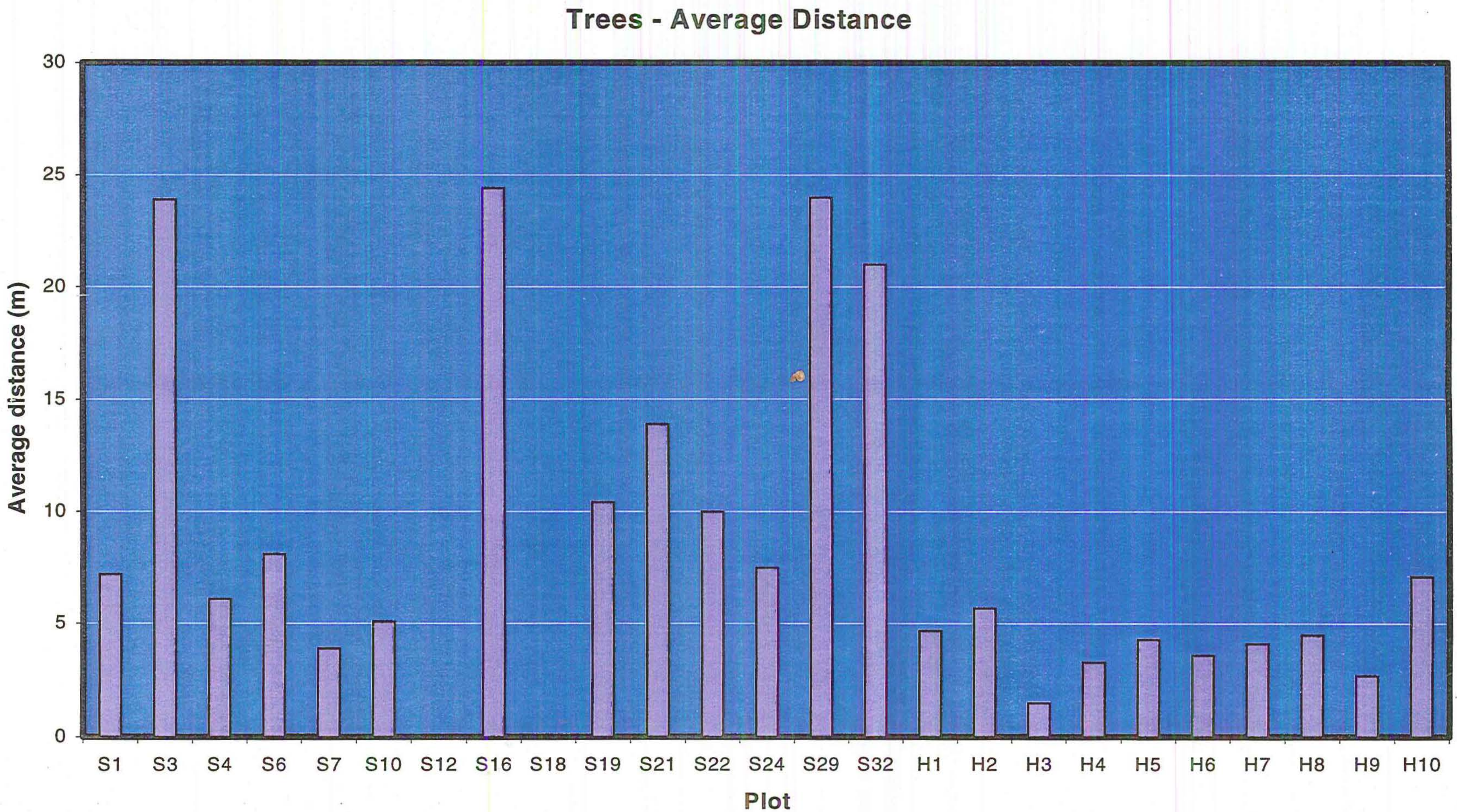

Fig 5.10; The average distance of trees at each of the sites. Plots prefixed by an S indicate escarpment plots and plots prefixed by a H indicate plots along the Serventy and Recher transect.

Foliage height diversity was uniform across plots (Fig 5.11), with the exception of escarpment plot 32 which consisted of low heath scrub with only two vegetation layers. Percent vegetation cover (Fig 5.12) was slightly more variable, with higher values often recorded on the escarpment. Weed ratings (not presented) were high in two main places. In the escarpment plots 12 to 21, the high overall weed rating was mainly attributable to bridal creeper. In the escarpment plots 4, 7, 22 and 24 and the Serventy and Recher transect plots 1, 2 and 5, the weed rating was mainly associated with a high veldt grass rating. A high number of layers, and a corresponding high structural diversity, was found in the escarpment plots at the south-western end of the escarpment (1 to 10) and in the transect plots 4 to10. Three of the escarpment disturbance plots (21, 22 and 24) had high ratings for clumping in the vegetation. Percentage cover values of each of the layers (not presented) showed high cover of the second layer in escarpment plots 1 to 10, high cover of the bottom and upper layers in escarpment plots 16 to 29 and lower cover of all layers along transect plots as compared to the escarpment.

The WMC data on percent cover of native and weed vegetation and bare ground (Fig 5.13) shows a higher percentage of native vegetation in the escarpment plots at the western end of the escarpment (plots 1 to 18) and two of the plots at the eastern end (plots 29 and 32). The other plots had greater weed cover. This pattern corresponded to weed ratings assigned by the Escarpment Project (not presented). The average maximum height of vegetation, another Escarpment Project variable, was greater in escarpment plots 3, 7 and 22 (not presented). Other features of the WMC variables (not presented) include low plant species richness, diversities and evenness in these disturbance plots.

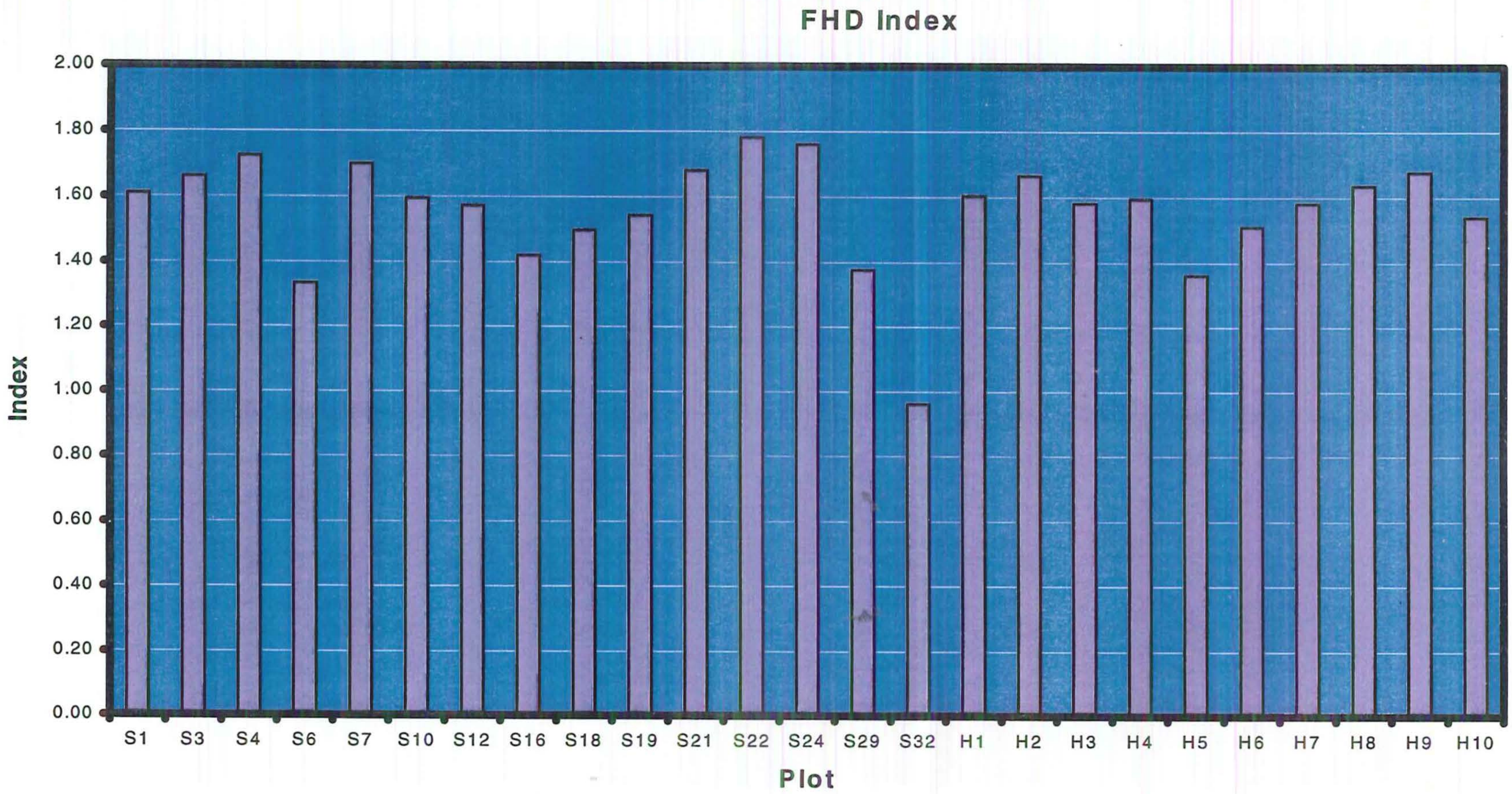

Fig 5.11; The foliage height diversity index at each of the sites. Plots prefixed by an S indicate escarpment plots and plots prefixed by a H indicate plots along the Serventy and Recher transect.

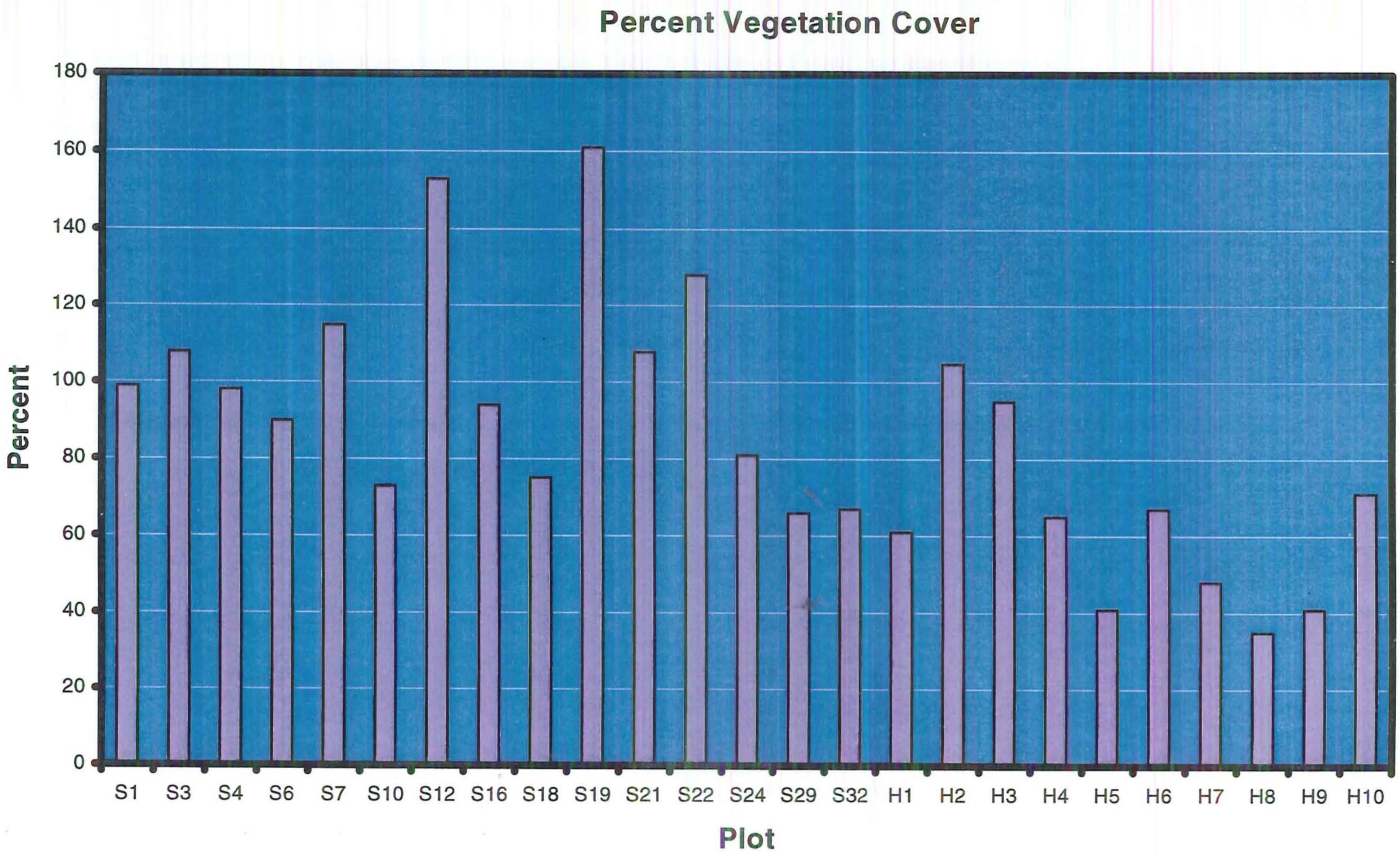

Fig 5.12; The percent vegetation cover at each of the sites. Plots prefixed by an S indicate escarpment plots and plots prefixed by a H indicate plots along the Serventy and Recher transect.

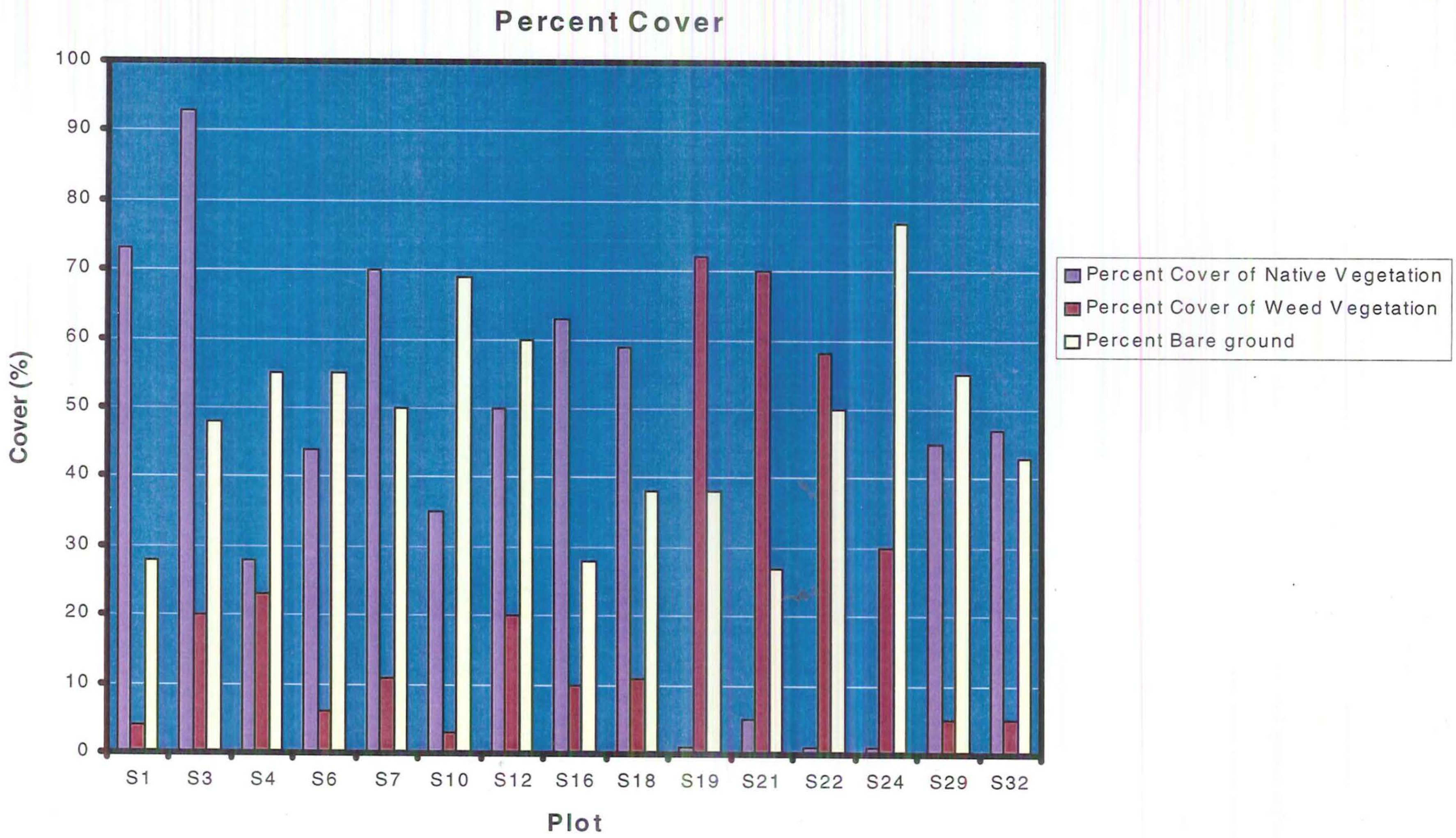

Fig 5.13; The percent cover of native vegetatation, weed vegetation and bare ground at each of the sites. Plots prefixed by an S indicate escarpment plots and plots prefixed by a H indicate plots along the Serventy and Recher transect.

5.3 Classifications and ordinations

Classification and ordination of the sites using bird data involved all plots from spring and summer, the escarpment and the park, and compared these as one unit (40 sites by 22 bird species). Appendix 3 shows the dendogram from PATN which was used to derive the bird classification.

5.3.1 *Classification of sites using bird data*

The classification of the bird data reveals some patterns which can be described by vegetation characteristics and some that are more difficult to explain (Fig 5.14). The sites did not separate into the Serventy and Recher transect and escarpment study areas. This is probably because some of the escarpment plots have similar vegetation to the Serventy and Recher plots. There was no separation between sites according to season. Group I of the classification included the spring escarpment sites of 1,3,6,16,18 and 32 as well as the summer escarpment site 1. These sites were all mainly composed of heath. In the second group the spring escarpment sites 10, 12 and 29 were those which had high densities of *Dryandra sessilis* and the same is true for the summer sites of 3, 10 and 12.

Group II includes the first half of the transect plots - 3, 4, 7, 8, 9 and 10. Group II is further subdivided into subgroups A and B. This separates spring sites 10 from 12 and 29, and park sites 3, 7 and 8 from 9, 10 and 4. Group III firstly was composed of the spring escarpment sites of 4 and 7 which are woodland sites. This grouping also includes the summer plots 29, 32, 4, 7, 21 and 16 and the remainder of the transect plots 1, 2, 5 and 6. The subdivision of group three separates spring escarpment sites 4 from 7, and summer escarpment sites 29 and 32 from 4, 7, 21 and 16. It also separates the transect plots 2 from 1, 5 and 6. The final grouping according to birds includes spring sites 19, 21, 22 and 24 which have all been grouped as 'disturbance' sites by the Escarpment Project ordination. Also in group IV are the summer escarpment plots of 18, 24, 6, 19 and 22.

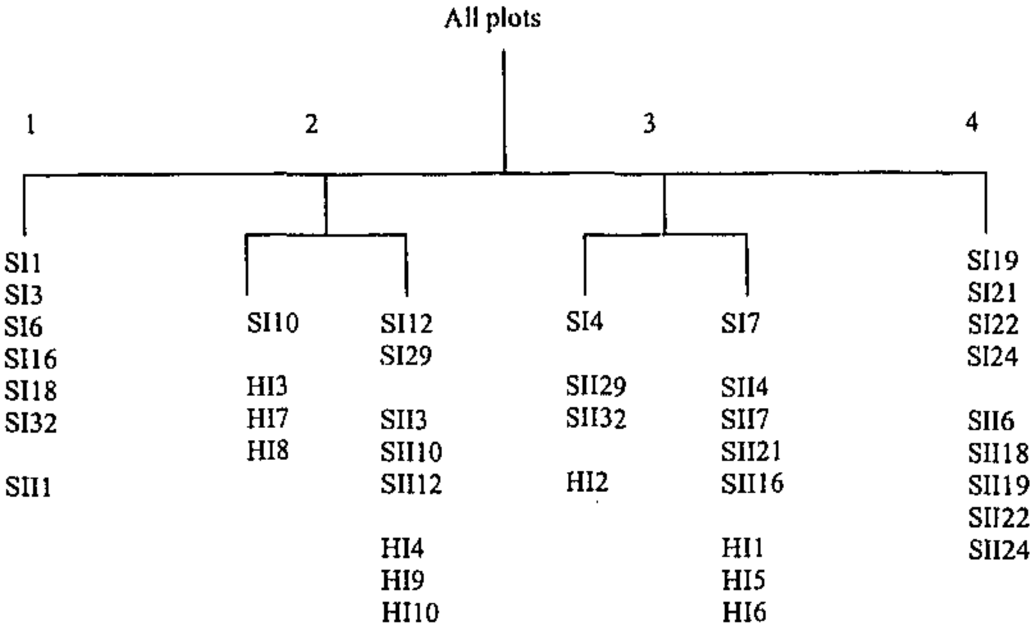

Fig 5.14; Classification of sites according to birds (Sites prefixed by S indicate plots on the escarpment and sites prefixed by H indicate plots along the Recher and Serventy Transect; I indicates spring sampling and II indicates summer sampling).

5.3.2 *Ordination of sites using bird data*

The majority of plots tended to ordinate around the centre of the ordination space with only a few outliers (Fig 5.15). The plots classified as disturbance by the vegetation ordination of the Escarpment Project also separated for birds except in the case of the escarpment plot 21 for the summer season. Other outliers, which are more difficult to explain, are the escarpment plot 16 and the transect plot 2 which ordinated near the disturbance plots on the right hand side of the graph. Scarp plots 1 (spring) and also 18 (summer) were also found to separate from the main group but away from the disturbance plots – potentially due to low bird abundances at these sites.

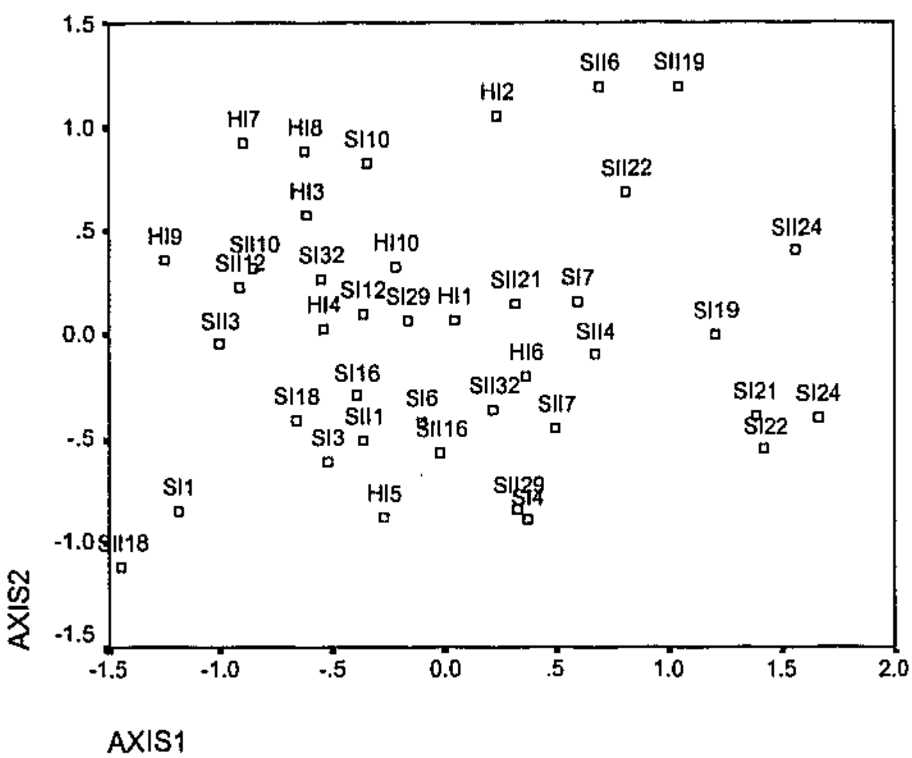

Fig 5.15; Ordination of the sites according to the bird variables

5.3.3 *Classification and ordination of sites by habitat*

Three separate classifications and ordinations were performed based on habitat variables. The first classification (Fig 5.16) and ordination (Fig 5.17), was based on the un-transformed variables percent vegetation cover and foliage height diversity. The Serventy and Recher transect plots all ordinated close to the centre of the ordination space indicating similarity in the vegetation according to these variables. Among the Serventy and Recher transect plots only plots 2 and 3 classified separately. The escarpment plots were more widely separated. Some grouped with the Serventy and Recher transect plots (6, 10, 16, 18, 29). Another large group formed in the centre of the ordination and corresponded to Group I in the classification. The most distinctively different plots in terms of these variables was escarpment plot 32 which is composed of very low heath and escarpment plots 12 and 19 which classified and ordinated away from the main grouping.

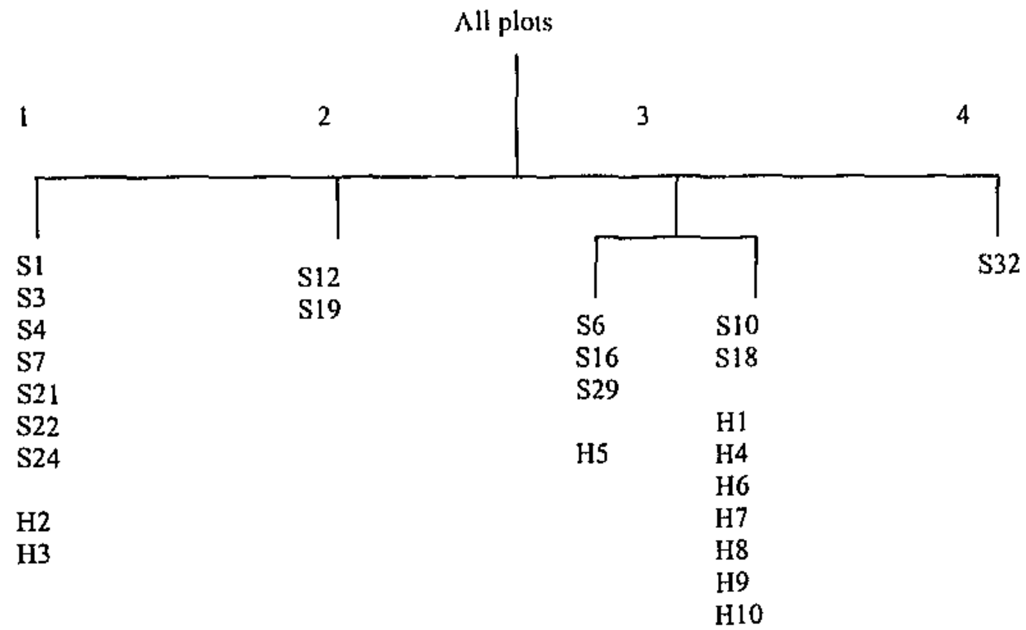

Fig 5.16; Classification of sites according the habitat variables percent vegetation cover and foliage height diversity (not transformed) (Sites prefixed by S indicate plots on the escarpment and sites prefixed by H indicate plots along the Recher and Serventy transect; I indicates spring sampling and II indicates summer sampling).

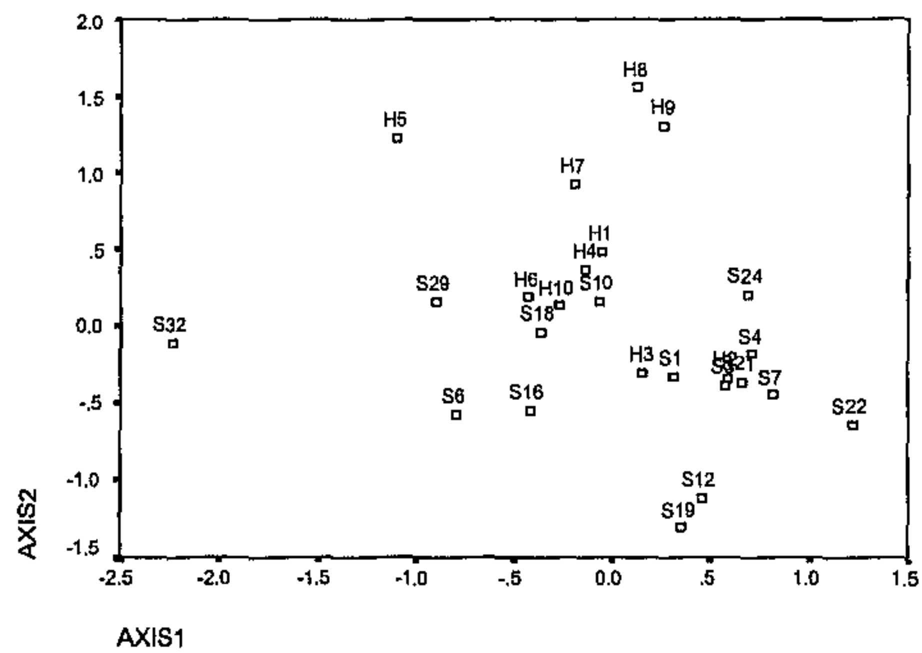

Fig 5.17; Ordination of the sites according to the habitat variables percent vegetation cover (log transformed) and foliage height diversity.

The second classification and ordination was based on foliage height diversity and a log transformed percent vegetation cover (Appendix 4). The effect of this initial transformation on the classification was only to form another group of separate Serventy and Recher transect plots (Group IV). The effect on the ordination was just to reflect data to the opposite ends of the ordination scale on the first axis without affecting any of the patterns and groupings.

The final classification and ordination was performed for vegetation using the variables of tree height, tree distance, percent vegetation cover (all log transformed), and foliage height diversity (Appendix 4). The most significant result of this analysis was that the Serventy and Recher transect plots classified and ordinated separately, except for the transect plots 2 and 3. The closeness with which the transect plots ordinated indicates the homogeneity of the plots in terms of vegetation. The escarpment plots, by contrast, were widely separated to the right of the ordination, with the exception of the plots which shared similar woodland features with the transect plots.

5.4 Correlations

There were a limited number of significant correlations between bird and habitat variables (Tables 5.9, 5.10 and 5.11). It should be noted that these tables do not include all of the variables analysed in the correlations because some variables produced no significant correlations. For example, only 17 of 22 bird variables used in the analysis showed significant correlations to habitat variables and only 20 of 30 habitat variables showed significant correlations to any bird variables. Of a total of 682 relationships analysed only 45 significant correlations were produced at the 0.05 significance level and only 7 at the 0.01 level. This is a very low number given that at the 0.05 level, 34 significant correlations would be expected by chance alone. At the 0.01 significance level, all seven significant correlations could have occurred by chance.

Table 5.9 - Matrix of significant correlations between bird (Spring) and habitat variables (Spearmans rank correlation coefficients, significance level of <0.05 except for figures in bold where the significance level is <0.01; Numbers in brackets indicate the sample size; BH = Brown Honeyeater, SH = Singing Honeyeater, RL = Rainbow Lorikeet; RW = Red Wattlebird)

	Bird Variable					
Habitat Variable	**Evenness**	**Richness**	**BH**	**SH**	**RL**	**RW**
Variables of this study:						
Veldt grass rating	0.641(15)			-0.525(15)		
Clumping		**-0.651(15)**	-0.549(15)	-0.559(15)		
Foliage height diversity	0.611(15)		**0.695(15)**			
Average height of layer 3		0.705(9)			0.779(9)	
Aspect			-0.516(15)			
Percent vegetation cover			-0.540(15)			
Percent cover of layer 1						0.620(15)
Percent cover of layer 2						-0.637(11)
Percent cover of layer 3				0.754(9)		
Trees – average height				**0.699(15)**		
WMC Variables:						
Percent cover of native vegetation						-0.615(15)
Percent weed cover quantitative			**-0.693(15)**			
Plant evenness index (J)					-0.523(15)	
Percent cover weed vegetation			**-0.724(15)**			
Plant diversity index (J)			0.588(15)			

Table 5.10 - Matrix of significant correlations between bird (Summer – summary) and habitat variables (Spearmans rank correlation coefficients, significance level of <0.05 except for figures in bold where the significance level is <0.01. Numbers in brackets indicate sample size.)

	Bird Summary Variable			
Habitat Variable	**Diversity**	**Evenness**	**Richness**	**Total Abundance**
Variables of this study:				
Bridal Creeper Rating	-0.410(25)			
Percent Cover of Layer 1	**0.600(25)**		0.412(25)	
Percent Cover of Layer 2			-0.471(19)	**-0.783(19)**
WMC Variables:				
Percent Cover Native Vegetation	-0.591(15)	-0.594(14)		
Plant Species Abundance			0.544(15)	

Table 5.11 - Matrix of significant correlations between bird (Summer – individual birds) and habitat variables (Spearmans rank correlation coefficients, significance level of <0.05 except for figures in bold where the significance level is <0.01; Numbers in brackets indicate sample size; BH = Brown Honeyeater; SH = Singing Honeyeater; RL = Rainbow Lorikeet; RW = Red Wattlebird; SH = Singing Honeyeater; WH = White-cheeked Honeyeater)

	Bird Abundance Variables					
Habitat Variable	**BH**	**SH**	**RL**	**RW**	**SH**	**WH**
Structural diversity rating			**-0.524(25)**			
Veldt grass rating				**0.512(25)**		
Number of layers			**-0.571(25)**			
Percent vegetation cover	-0.480(25)	**0.553(25)**				
Trees – average distance			0.457(25)			
Trees – average height	-0.401(25)		0.406(25)			
Percent cover of layer 2	-0.483(19)					
Percent cover of layer 3	-0.498(16)					
Percent cover of layer 4			0.552(17)			
Average height of layer 4						-0.533(17)
WMC Variables						
Percent weed cover quantitative						-0.609(15)
Plant species evenness		-0.525(15)				0.572(15)
Percent cover weed vegetation						**-0.770(15)**
Plant diversity index						0.534(15)

Only two of the bird summary variables for spring showed significant correlations with the habitat variables. Evenness was significantly correlated with the veldt grass rating ($r = 0.641$, df = 14, $p<0.05$) and with the foliage height diversity ($r = 0.611$, $p<0.01$). Richness was negatively correlated with clumping ($r = -0.651$, df = 14, $p<0.01$) and with the average height of the third vegetation layer ($r = 0.705$, df = 8, $p<0.05$).

The abundance of Brown Honeyeaters in spring was significantly correlated with seven of the habitat variables. The direction of the correlation was positive for foliage height diversity ($r = 0.695$, df = 14, $p = 0.01$) indicating that the species was found most frequently in a structurally diverse habitat. Negative relationships were found with the clumping rating ($r = -0.549$, df = 14, $p<0.05$), percent vegetation cover ($r = -0.540$, df = 14, $p<0.05$)(Fig 5.18), percent weed cover quantitative rating ($r = -0.693$, df = 14, $p<0.01$) and percent weed cover ($r = -0.724$, df = 14, $p<0.01$)(Fig 5.19). High weed cover is associated with the disturbance sites, as classified by the WMC ordination. This correlation therefore indicates that Brown Honeyeaters are more abundant on undisturbed sites. This conclusion is supported by the positive correlation with the plant diversity index ($r = 0.588$, df = 14, $p<0.05$). Singing Honeyeaters in spring were significantly correlated with four habitat variables, the most important relationship being with average height of trees ($r = 0.699$, df = 14, $p<0.01$). Data for Red Wattlebirds in spring revealed a negative correlation with the percent cover of native vegetation indicating that, unlike Brown Honeyeaters, Red Wattlebirds are more abundant on the disturbed sites.

In summer, all four of the bird summary variables showed significant correlations with habitat variables. Significant negative correlations were found for bird species diversity and the bridal creeper rating ($r = -0.410$, df = 24, $p<0.05$), and with percent native vegetation cover ($r = -0.591$, df = 14, $p<0.05$). Evenness was also negatively correlated with the percent cover of native vegetation cover ($r = -0.594$, df = 13, $p<0.05$). This means that the sites with less native vegetation had a greater diversity and evenness of bird species.

Individual bird species in summer that showed significant correlations with habitat variables were the Brown Honeyeater, Singing Honeyeater, Rainbow Lorikeet and White-cheeked Honeyeater. Responses to habitat variables differed between bird species. The Brown Honeyeater was negatively correlated with percent vegetation cover ($r = -0.480$, df = 24 $p<0.05$), while the Singing Honeyeater was positively correlated ($r = 0.553$, df = 24, $p<0.01$). For average tree height, Brown Honeyeaters were positively correlated ($r = -0.401$, df = 24 $p<0.05$) and Rainbow Lorikeets were negatively correlated ($r = 0.406$, df = 24 $p<0.05$). White-cheeked Honeyeaters were negatively correlated with the percent cover of weed vegetation ($r = -0.770$, df = 14, $p<0.01$).

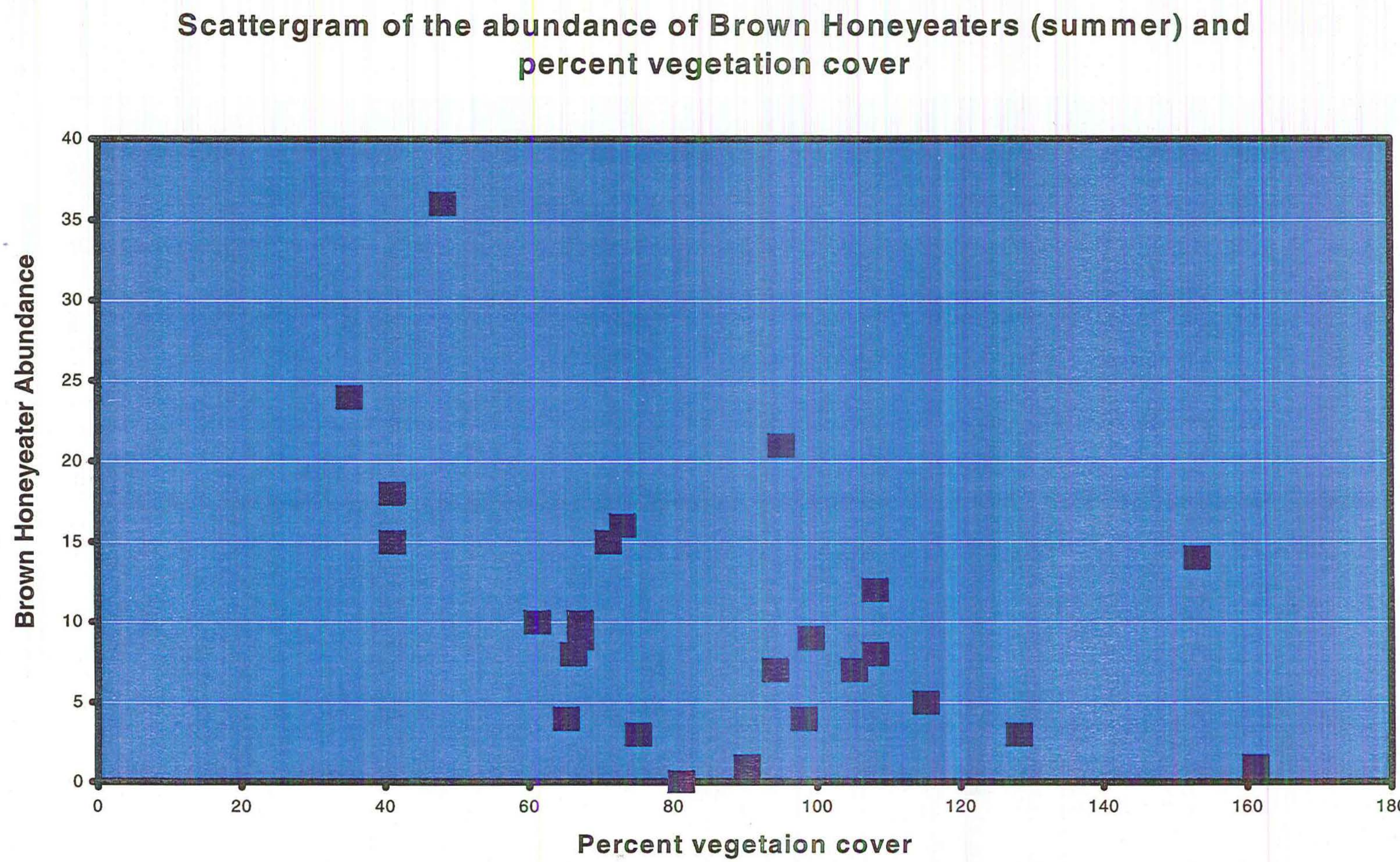

Fig 5.18; Scattergram showing the relationship of the abundance of Brown Honeyeaters in summer with percent vegetation cover ($r = -0.480$, $df = 24$, $p = 0.05$).

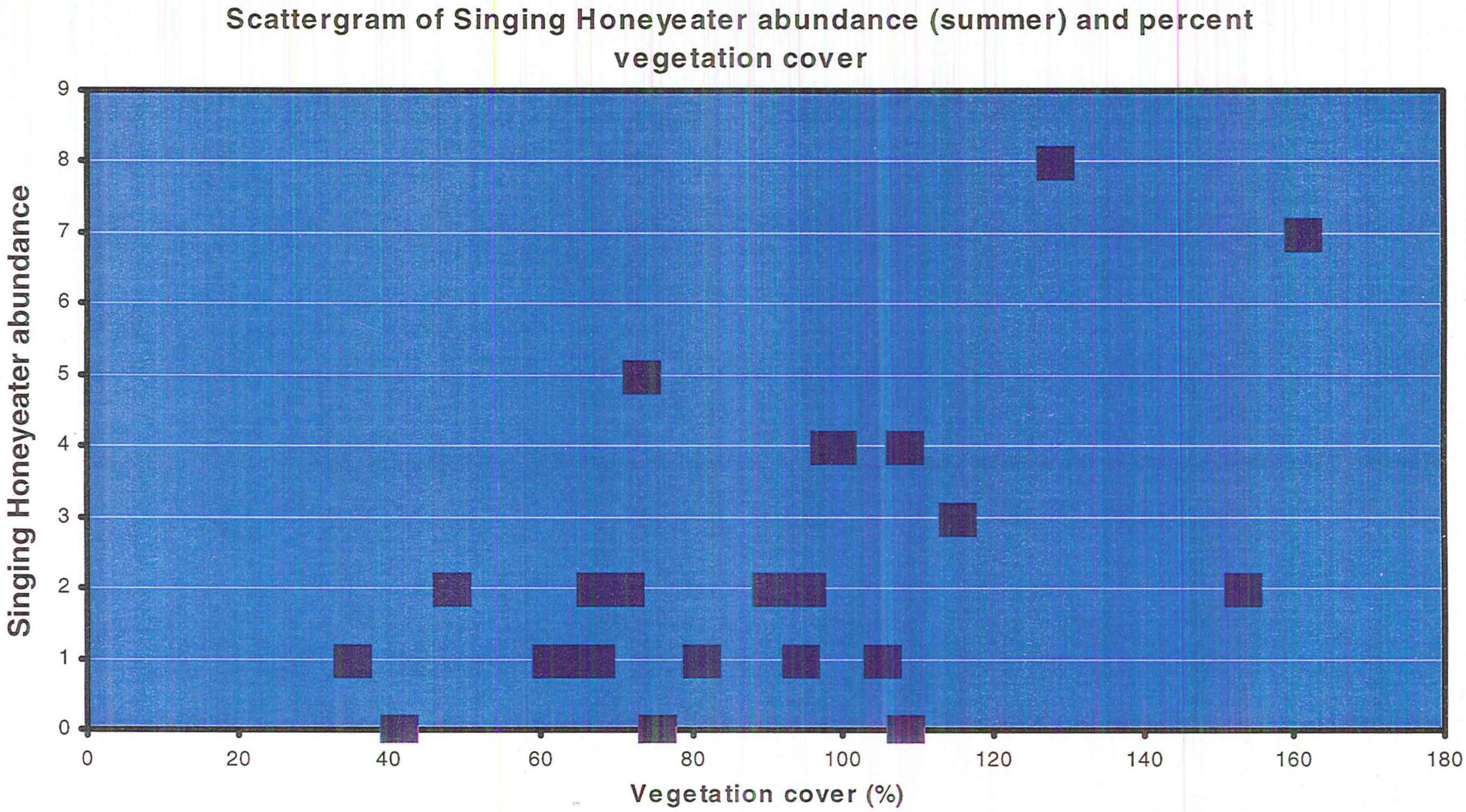

Fig 5.19; Scattergram showing the relationship of the abundance of Singing Honeyeaters in summer with percent vegetation cover ($r = 0.553$, $df = 24$, $p = 0.01$).

5.5 Transect data

5.5.1 *Analysis of data from the Serventy and Recher transect*

Bird data recorded for each section of the Serventy and Recher transect showed that there was a greater density of birds on the final section of the transect (Table 5.12). This final section was the only unburnt section. Total abundance also declined from the first section, which was at the northern end of the transect, to the fourth section towards the southern end. Richness of birds was relatively constant except for the fourth section, where the greater length of the section was probably the reason for the greater richness.

Table 5.12; Serventy and Recher Summary Statistics (data summarized from 24/2/96 to 16/3/96 and 15/4/97 to 17/2/98)

		Section				
	Total	**1**	**2**	**3**	**4**	**5**
Length (m)	1376	302	217	194	453	210
Total abundance of birds	15157	3648	2577	1920	3968	3045
Density of birds (birds/m)	11.0	12.1	11.9	9.9	8.8	14.5
Total richness of birds	44	26	26	29	36	30
Burnt(B)/Unburnt (U)		B	B	B	B	U

Statistics for individual species along the transect were also analysed and compared to habitat data (Appendix 5). Individual species such as the Australian Magpie, Galah, Laughing Kookaburra, Port Lincoln Parrot, Rainbow Lorikeet and Red Wattlebird were all more abundant at either end of the transect. These are all large, habitat generalist species which are using the playground vegetation in section one and the nearby gardens of the University of Western Australia in section five, for their habitat.

5.5.2 *Transect data and differences highlighted*

The Serventy and Recher transect was surveyed twice and compared to three surveys of the law walk transect (Table 5.9). Both densities of birds and species richness were higher on the Serventy and Recher transect than the Law Walk transect.

Table 5.9; Comparison of abundance and richness of birds on the two transects.

	Transect	
	Serventy and Recher	**Law Walk**
Dates sampled	24/11/97, 7/10/97	24/9/97, 23/10/97, 11/11/97
Length of transect (m)	1376	1800
Mean total abundance (birds/survey)	111.5	80.3
Density (birds/m)	0.1	0.04
Mean species richness (species/survey)	10.5	8.3

One of the reasons for conducting these transects was to identify any birds that were missed in the point counts. For the Serventy and Recher transect the birds identified were the Galah and the Australian Raven. For the Law Walk transect, the birds were the Black Faced Cuckoo Shrike (*Coracina novaehollandiae*) and the Wood Duck (*Chenonetta jubata*).

5.6 Summary of major results

There are considerable differences in the bird communities of the two study areas, the Serventy and Recher transect and the Mt Eliza Escarpment. The most notable of these is the low abundance of insectivores on the Mt Eliza Escarpment. There are also differences between the communities occupying disturbed and undisturbed plots of the Mt Eliza Escarpment. The main difference is in the composition of the birds in each area, including higher numbers of introduced bird species on the disturbance plots. Examination of the patterns of abundance, richness, diversity and evenness of the bird community and the abundance of individual species, indicates relationships with patterns in the habitat. A different community of birds was found to inhabit different habitat types such as heath, *Dryandra sessilis* stands and woodland. Few correlations were found, between bird and habitat variables and few specific relationships could be described.

Chapter 6: Discussion

6.1 Introduction

Making accurate predictions as to how a community of animals will respond to changes in their habitat is the ultimate goal of ecologists. This is probably never attainable, but any understanding is useful (Recher, 1985). This applies for the community of birds in Kings Park where understanding the relationship of birds to their habitat is vital for conservation of the avifauna. Conservation of the avifauna is achieved through recognition of the requirements of the species in need of protection. Habitat disturbance is a key factor shaping communities and understanding of how it operates provides the means for regulating its effects (Chesson and Case, 1986). In the highly disturbed ecosystem of Kings Park understanding of the way in which disturbance operates is necessary for minmising its effects.

The first part of this chapter will deal with the results by considering the two questions that this project set out to answer – are birds related to their habitat? and do birds respond to disturbances in the habitat? The second part will take the major results to justify management recommendations for the Mt Eliza Escarpment and in particular for the Escarpment Project and for Kings Park. The third part will consider possible future research that has been identified as a way of achieving even better conservation through management. The thesis ends with some conclusions that summarize the major recommendations for Kings Park to ensure that it continues as a functioning habitat for birds.

6.2 Discussion of main results

6.2.1 *Birds and habitat features*

Birds are closely related to the habitats in which they live (Recher, 1985). Understanding of which components of the habitat are most important in influencing bird communities is a question which is asked in many ecological studies (e.g. Hino, 1985, Terbough *et al.*, 1990). It is also important to know just how closely the bird community will respond to each of these variables (Arnold, 1988). In Kings Park, it appears that birds are responding to features of their habitat but not in ways which are closely linked to particular habitat variables. Highly specific relationships are more likely to be found when comparing two or more very different habitats, with greater variation than is found in Kings Park (Cody, 1993).

On a smaller scale, birds tend to respond more generally to the habitat (MacArthur, 1965). Within Kings Park, patterns of habitat variables were found, in some cases, to match patterns in the distribution and abundance of birds. Classification of the sites studied grouped plots into sites that matched some of the broad habitat types including *Dryandra sessilis* stands, heath plots and woodland plots.

Utilising feeding guilds of birds is a valuable way of examining the differences in the bird communities between two areas (Terbough and Robinson, 1986). Comparison of the two study areas, the escarpment and the transect, revealed differences in the guild structure of the two areas including a lack of insectivores on the escarpment (Table 5.5). The abundance of insect feeding birds in an area is related to the abundance of foraging substrates. This is directly linked to the structure of the vegetation (Gilmore, 1985). There are distinct differences in the structure of the transect vegetation and the escarpment vegetation. Trees are much more widely spaced on the escarpment and differ in the types of species present. There are very few eucalypts on the escarpment compared to the transect. Eucalypts provide important foraging substrates for insectivores such as Weebills and Yellow

Rumped Thornbills (Recher *et al.*, 1996). Another tree which is more common on the transect is the casuarina (*Allocasuarina fraseriana*) and is also an important foraging substrate for the insectivorous Western Warbler and Rufous Whistler (H. Recher, pers. comm.).

The shallowness and poor nutrient status of the soils on the Mt Eliza Escarpment is another factor that might explain the lack of insectivores. All of Kings Park is nutrient poor but the limestone escarpment is even more so. Soil nutrients have a direct relationship to foliar nutrients which in turn are related to the abundance of arthropods on the leaves of trees, on which the insectivores feed (Recher *et. al.*, 1996).

6.2.2 *Birds and habitat disturbance*

Disturbance to Australian environments has been on-going since the arrival of the first settlers in 1788 (Saunders, 1985). The long history of disturbance in Kings Park means that the park is already in a highly altered state. (Beard, 1967). As a result of this long period of disturbance, the birds that are most sensitive to change have already disappeared from the park (Recher and Serventy, 1991; Recher, 1997). Despite the absence of these birds, ordination of the bird community was still able to separate disturbed from non-disturbed plots on the Mt Eliza Escarpment (Fig 5.5). Examination of the birds present at disturbed and non-disturbed plots showed that total abundance, species richness, diversity and evenness were similar for the two areas, but that the composition of the bird communities was changed.

Exotic species of birds are common in highly disturbed environments such as urban parks (Mansell, 1997). One of the major differences between the composition of disturbed and undisturbed sites was that areas with greater disturbance had greater numbers of introduced bird species such as the Laughing Turtledove. They also had less native species such as the Brown Honeyeater. Native bird species feed mainly on native plants while introduced bird species tend to feed on both native and introduced plants (Williams and Karl, 1996). Disturbed sites were characterised in the Escarpment Project ordination as having a high percentage of weed cover and low percentage of native vegetation cover. The disturbed sites appear to be providing a food source for these introduced species but not for some of the native species.

6.3 Management guidelines

6.3.1 *General guidelines*

Management objectives have been established for the Mt Eliza Escarpment and the remainder of Kings Park (see Dixon *et al.*, 1995 and Anon., 1997). The key management objective for both areas is to maintain the existing natural species and the processes that sustain them, with particular emphasis upon rare species (Dixon *et al.*, 1995; Anon., 1997). Ecological studies are commonly undertaken to generate management guidelines for the conservation of bird communities (e.g. Loyn, 1985; Ford and Bell, 1980; Robinson, 1992; Shields *et al.*, 1985). These guidelines should meet management objectives and reflect both public and ecological values given to the bird community.

Public values of birds in urban parks were examined in a study by Mansell (1997). She conducted a survey on the value of birds to the users of urban parks and showed that although birds are not the most important feature of the parks (they were ranked sixth out of eight options), that they are valued (93 out of 100 people thought that steps should be taken to encourage birds). She also found that the three most desirable bird species were the Galah and two introduced species, the Laughing Kookaburra and Rainbow Lorikeet. These preferences seem to indicate that the public is generally unconcerned or uninformed about smaller, less abundant species. It appears that most members of the public are concerned about protection of the overall bird community, but less so of particular bird species. This is especially relevant when considering how to deal with disturbance on the Mt Eliza Escarpment, which only causes a changed composition of the bird community and not abundance or diversity.

In terms of the scientific, heritage and ecological values of Kings Park, a changed composition of the bird community is important. The significance of Kings Park as an ecological refuge is illustrated by its listing in the System 6 report (Department of Conservation and Environment, 1981). This is not only due to its individual value but also to its value as a corridor for bird species moving across the Swan Coastal Plain.

For maintenance of existing species, the first guideline is that disturbance must be minimised. Disturbance is a process found in all ecosystems which can act to reduce competitive exclusion and stabilise communities (De Angelis and Waterhouse, 1987). Excessive disturbance however, can start to alter the bird community. On the Mt Eliza Escarpment disturbance appears to be acting to change the composition of the bird species present. The same process is occurring on the Serventy and Recher transect (Recher and Serventy, 1991).

The second guideline is to provide a diverse habitat to meet the requirements of the highest possible number of bird species. Each individual bird species within a bird community has requirements which must be met if it is to occupy a patch of habitat. In eastern Australia Scarlet and Flame Robins, for example, only occupy habitats with open ground layers of grass or bark and a sparse shrub and sapling layer (Robinson, 1992). The Flame Robin does not occur in Western Australia but the Scarlet Robin has disappeared from Kings Park because its requirement for an open ground layer was not met.

6.3.2 *Kings Park*

Disturbances in Kings Park which impact upon the bird community include a decline in the canopy of eucalypts, a spread of ground covering weeds and an altered fire regime. Minimising each of these disturbances is a priority for the management of birds in the park (Recher, 1997). Reversing the decline in the eucalypt canopy is vital for insect feeding birds. Reducing the spread of weed cover in the park is necessary to maintain native flora and the birds which feed upon them. Weeds also contribute to the incidence of fires in the park. Fires in turn are responsible for the proliferation of weeds and the death of eucalypts (Wycherley, 1983).

The regeneration of certain areas of the park is also important for the bird community, especially for re-introduction or recolonisation of birds that have been lost from the park. Regeneration procedures should include creating weed free areas, replanting eucalypt species and planting other native species to create a structurally and floristically more diverse environment which meets the requirements of the greatest number of species (Beard, 1967; Currie, 1991).

6.3.3 *The Mt Eliza Escarpment*

The Mt Eliza Escarpment is a distinct part of Kings Park in need of special management attention. The habitat of the escarpment is diverse in terms of its structure, floristics and level of disturbance. Unique management is needed on the Mt Eliza Escarpment to deal with the range of factors influencing the bird community (Anon., 1997). Management must recognise the differentiation of the escarpment into disturbed and non-disturbed sites. At non-disturbed sites the major priority is to minimise disturbance. Disturbed sites become the focus of restoration work.

Major components of the restoration planned for the escarpment include removal of weeds and regeneration of degraded areas (Anon., 1998). Effective regeneration of the escarpment for conservation of the bird community can be achieved by ensuring that regeneration provides for the greatest possible structural and floristic diversity in the vegetation. This should include areas of bare ground, areas of dense shrubbery, areas of taller trees (including eucalypts) and areas of low heath. Regeneration should not necessarily involve removal of all weeds on the escarpment, only those which threaten native flora. Observations of birds feeding and perching on the weed *Agave americans* (Plate 6.1) indicate that it is an important habitat resource for birds.

6.4 Limitations and further study

6.4.1 *Limitations of my study*

There were four major limitations in this study. Firstly the study was limited simply by its spatial and temporal coverage. Secondly was the fact that intensity of sampling limited the ability to draw conclusions. More sampling effort in terms of both birds and habitat variables would have allowed much more specific guidelines to be generated instead of just broad factors. Thirdly was the lack of control in comparing habitats of different disturbance due to the lack of non-disturbed areas in Kings Park. The final limitation was that, because many species of birds have already disappeared from Kings Park, their habitat requirements could not be assessed. For these species to be re-introduced into the Park their requirements will first have to be assessed in a different area.

6.4.2 *Further study*

The following major areas have been identified for further study:

- Assessing habitat requirements and utilisation in areas outside of Kings Park to determine features of less disturbed environments which might be more optimal for conservation of the bird community – this will allow the park to be regenerated in such a way as to facilitate the return of birds that have been lost from the park.
- On the suitability of the conclusions I have drawn for Kings Park for other areas of urban bushland and how they would be applied in the particular habitat types of each patch of urban bushland.
- Studies to look more closely at individual bird species and individual habitat factors and disturbance agents.
- To look closely at the feeding habits of native and introduced bird species and determine if they have preferences for native or introduced plants.
- To determine the precise effect of fire upon the avifauna by comparing more areas of burnt and unburnt vegetation.

- To consider the possibility of re-introducing birds into the park and how it might be done effectively.
- To closely consider the impact of the removal of weeds upon the bird community.
- To closely consider the need for eucalypts and canopy tree species for insect feeding birds.
- To determine how the avifauna can be expected to change in the future.

6.5 Conclusions

Kings Park is a highly disturbed ecosystem in which the existing suite of species cannot be maintained without intervention. In some ecological communities, disturbance is a factor that acts to reduce competitive exclusion and allow species to persist over time (DeAngelis and Waterhouse, 1987). This only applies however if the level of disturbance is not excessive. Kings Park is a highly disturbed ecosystem. As a result, some of the existing, native species are unable to cope and are being progressively overcome by a new set of species.

To maintain the existing species, intensive management intervention is required. This must be through an understanding of how the processes of disturbance are acting and how birds and habitat are related. To achieve this goal the following major recommendations are made:

- Minimise the level of disturbance, particularly in the form of weeds and fire.
- Maintain a diverse habitat to meet the requirements of a broad range of bird species.
- Undertake further study upon particular bird species in need of special protection and individual habitat factors and disturbance agents.

Kings Park will never be a disturbance free environment. It must be accepted that the park is in a state of constant change due to the changing city around it and the disturbances it receives from within (Richards, 1982). Management goals should be to try to minimise these changes and maintain Kings Park in as natural and valuable state as is possible for the people of Perth.

Plate 6.1; Port Lincoln Parrot perched on agave (*Agave americans*) (Source: Ray Wills).

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APPENDIX 1

Table 1; Matrix of the abundance of each species of bird and summary variables recorded at each plot for spring and summer and for both the Mt Eliza escarpment and the Serventy and Recher transect.

Key:
S = Mt Eliza escarpment plot
H = Serventy and Recher plot
I = First sampling occasion i.e. spring for the escarpment and summer for the transect
II = Second sampling occasion i.e. summer for the escarpment
AM = Australian Magpie
AR = Australian Raven
BH = Brown Honeyeater
G = Galah
K = Laughing Kookaburra
LT = Laughing Turtledove
LW = Little Wattlebird
PP = Portlincoln Parrot
RB = Rainbow Bee-eater
RL = Rainbow Lorikeet
RW = Red Wattlebird
RWH = Rufous Whistler
SE = Silver-eye
SH = Singing Honeyeater
SD = Spotted Dove
SP = Striated Pardalotte
W = Weebill
WS = Western Spinebill
WH = White-cheeked Honeyeater
WTB = White-tailed Black Cockatoo
WW = Western Warbler
YRT = Yellow Rumped Thornbill

Plot	AM	AR	BH	G	K	LT	LW	PP	RB	RL	RW	RWH	SE	SH	SD	SP	W	WS	WH	WTB	WW	YRT	Tot. Ab.	Richness	Diversity	Eveness
SI1	0	1	5	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	15	4	1.06	0.77
SI3	0	0	8	0	0	1	0	0	0	0	0	0	0	2	0	0	0	0	6	0	0	0	17	4	1.14	0.82
SI4	0	0	6	0	0	2	0	0	0	15	2	0	1	4	0	0	0	0	5	0	0	0	35	7	1.62	0.83
SI6	0	0	8	0	0	1	0	0	0	0	3	0	0	5	0	0	0	0	5	0	0	0	22	5	1.24	0.77
SI7	0	0	6	0	0	0	3	3	0	0	6	0	0	1	0	0	0	0	0	0	0	0	19	5	1.47	0.91
SI10	0	2	26	0	0	1	0	0	0	6	2	0	0	2	0	0	0	0	0	0	0	0	39	6	1.11	0.62
SI12	0	0	15	0	0	3	0	0	0	1	1	0	0	6	0	0	0	0	4	0	0	0	30	6	1.23	0.69
SI16	0	0	12	0	0	1	0	0	0	0	3	0	0	1	0	0	0	0	6	0	0	0	23	5	1.23	0.76
SI18	0	0	11	0	0	0	0	0	0	0	1	0	0	2	0	0	0	0	10	0	0	0	24	4	1.06	0.77
SI19	0	0	1	0	0	1	0	1	0	4	10	0	0	4	0	0	0	0	0	0	0	0	21	6	1.42	0.79
SI21	0	0	0	0	0	3	0	0	0	0	15	0	0	3	0	0	0	0	4	0	0	0	25	4	1.11	0.80
SI22	0	0	0	0	0	5	0	0	0	0	7	0	0	2	0	0	0	0	0	0	0	0	14	3	0.99	0.90
SI24	0	0	0	0	1	3	0	0	0	0	3	0	0	1	0	0	0	0	0	0	0	0	8	4	1.26	0.91
SI29	0	0	15	0	0	3	0	0	0	0	5	0	0	5	0	0	0	0	3	0	0	0	31	5	1.39	0.86
SI32	0	0	19	0	0	0	1	1	2	0	3	0	0	2	0	0	0	0	10	0	0	0	38	7	1.40	0.72
SII1	0	0	9	0	0	1	0	0	0	0	1	0	0	4	1	0	1	0	6	0	0	0	23	7	1.57	0.81
SII3	0	0	12	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	14	3	0.51	0.46
SII4	0	0	4	0	0	1	0	1	0	0	5	0	2	4	0	0	0	0	0	0	0	0	17	6	1.63	0.91
SII6	0	0	1	0	0	0	0	0	0	1	1	0	1	2	0	0	0	0	0	0	0	0	6	5	1.56	0.97
SII7	0	0	5	0	0	0	0	0	0	0	4	0	0	3	0	0	0	0	0	0	0	0	12	3	0.94	0.85
SII10	0	0	16	0	0	0	0	0	0	0	0	2	0	5	0	0	0	0	1	0	0	0	24	4	0.94	0.68
SII12	0	0	14	0	0	0	0	0	0	0	0	0	3	2	1	0	0	0	0	0	0	0	20	4	0.91	0.66
SII16	0	0	7	0	0	0	0	0	0	0	3	0	2	1	0	0	0	0	2	0	0	0	15	5	1.40	0.87
SII18	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0.00	0.00
SII19	0	0	1	2	0	1	0	3	6	8	0	0	2	7	0	0	0	0	0	1	0	0	31	8	1.92	0.92
SII21	0	0	8	0	0	2	0	2	0	3	3	0	0	4	0	0	0	0	0	0	0	0	22	6	1.66	0.92
SII22	0	1	3	0	0	0	0	0	1	2	5	0	10	8	0	0	0	0	0	0	0	0	30	7	1.65	0.85
SII24	0	0	0	0	0	2	0	1	0	3	2	0	0	1	0	0	0	0	0	0	0	0	9	5	1.52	0.95
SII29	0	0	8	0	0	0	0	0	1	13	6	0	1	1	0	0	0	0	4	0	0	0	34	6	1.58	0.88
SII32	0	0	10	0	0	2	0	1	1	4	9	0	2	1	0	0	0	0	5	0	0	0	35	9	1.76	0.80
HI1	0	0	10	0	0	0	0	1	0	0	4	0	2	1	0	0	4	0	0	0	1	0	23	7	1.59	0.82
HI2	2	0	7	0	0	0	0	3	0	19	3	0	0	1	0	0	4	0	0	0	0	1	40	8	1.61	0.78
HI3	0	0	21	0	0	0	0	1	0	0	1	0	0	2	0	0	0	0	0	0	0	1	26	5	0.75	0.46
HI4	0	0	4	0	0	0	0	2	0	0	2	0	0	1	0	1	0	0	0	0	0	0	10	5	1.47	0.91
HI5	0	0	18	0	0	0	0	0	2	0	4	1	0	0	0	0	1	0	0	0	0	4	30	6	1.25	0.70
HI6	0	0	9	0	0	0	0	0	0	0	10	0	1	2	0	0	1	1	0	0	2	2	28	8	1.66	0.80
HI7	0	0	36	0	0	1	0	0	0	0	0	0	1	2	0	1	0	0	0	0	0	0	41	5	0.53	0.33
HI8	0	0	24	0	1	0	0	0	0	0	2	0	6	1	0	1	2	0	0	0	2	0	39	8	1.33	0.64
HI9	0	0	15	0	0	0	0	0	0	0	0	3	4	0	0	0	0	0	1	0	0	1	24	5	1.12	0.69
HI10	0	0	15	0	0	1	0	0	0	0	4	0	2	2	0	0	0	0	0	0	0	3	27	6	1.36	0.76

APPENDIX 2

Table 1; Values of the Chi-square analysis used for birds of the Mt Eliza escarpment in spring.

Variable	**Degrees of Freedom**	χ^2	**Significance level (if less than 0.05)**
AR	2	19.2	0.001
BH	9	3.00	Not significant
LT	4	4.67	Not significant
K	1	11.20	0.001
SE	1	11.27	0.001
SH	6	6.00	Not significant
PP	2	14.80	0.001
RB	1	11.26	0.001
RL	4	26.67	0.001
RW	8	4.80	Not significant
WH	6	5.07	Not significant

Table 2; Chi-square analysis for the birds in summer for the Recher and Serventy transect plots.

Variable	**DF**	χ^2	**Significance level (if <0.05)**
AM2	1	6.4	0.025
BH2	8	0.8	Not Significant
K2	1	6.4	0.025
LT2	1	3.6	Not Significant
PP2	3	6.8	Not Significant
RB2	1	6.4	0.025
RL2	1	6.4	0.025
RW2	5	2.0	Not Significant
RWH2	2	9.8	0.01
SE2	4	3.0	Not Significant
SH2	2	0.8	Not Significant
SP2	1	1.6	Not Significant
W2	3	3.6	Not Significant
WH2	1	6.4	0.025
WS2	1	6.4	0.025
YRT2	4	4.0	Not Significant

Table 3; Chi-square analysis for the birds in summer for the Mt Eliza escarpment plots.

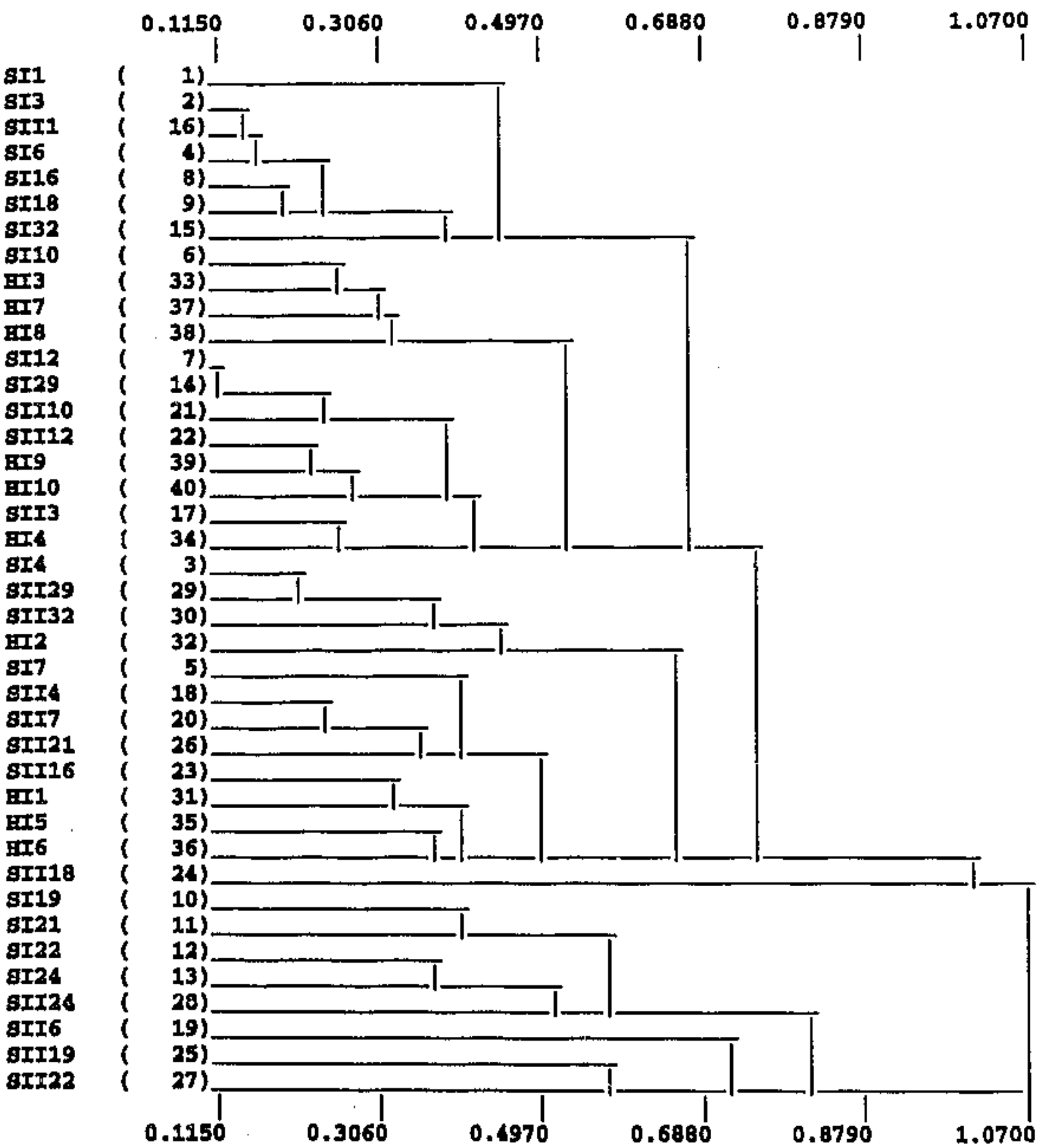
Variable	**DF**	χ^2	**Significance level (if <0.05)**
AR2	1	11.3	0.001
BH2	11	1.8	Not Significant
G2	1	11.3	0.001
LT2	2	2.8	Not Significant
PP2	3	14.6	0.005
RB2	2	11.2	0.005
RL2	6	13.5	0.05
RW2	7	6.9	Not Significant
RWH2	1	11.3	0.001
SD2	1	8.1	0.005
SE2	4	8.7	Not Significant
SH2	7	4.7	Not Significant
W2	1	11.3	0.001
WH2	5	27	0.001
WTB2	1	11.3	0.001

APPENDIX 3

Figure 1; Dendogram used to classify birds from PATN.

Kpbirds

02/26/98 14:28:04.91 DEND Kings Park Birds



APPENDIX 4

Fig 1; Classification of sites according to the habitat variables percent vegetation cover and FHD Index (not transformed)(Sites prefixed by an S are plots on the escarpment and those prefixed by a H are those on the Recher and Serventy transect).

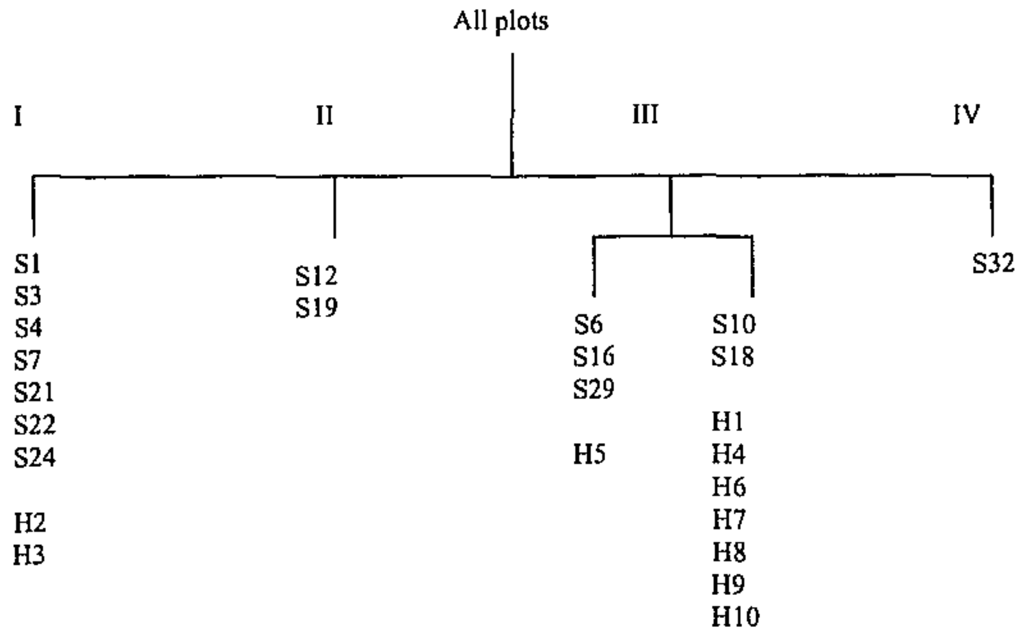


Fig 2; Classification of sites according to the habitat variables percent vegetation cover (log transformed) and FHD Index (Sites prefixed by an S are plots on the escarpment and those prefixed by a H are those on the Recher and Serventy transect).

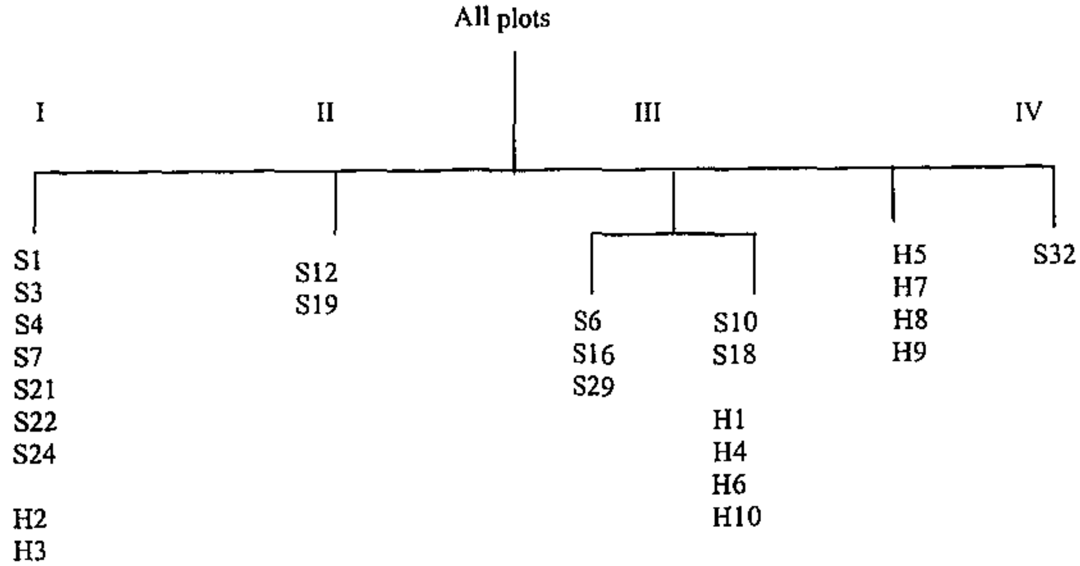


Fig 3; Classification of sites according to the habitat variables of tree distance, tree height and percent vegetation cover (all log transformed) and FHD (Sites prefixed by an S are plots on the escarpment and those prefixed by a H are those on the Recher and Serventy transect).

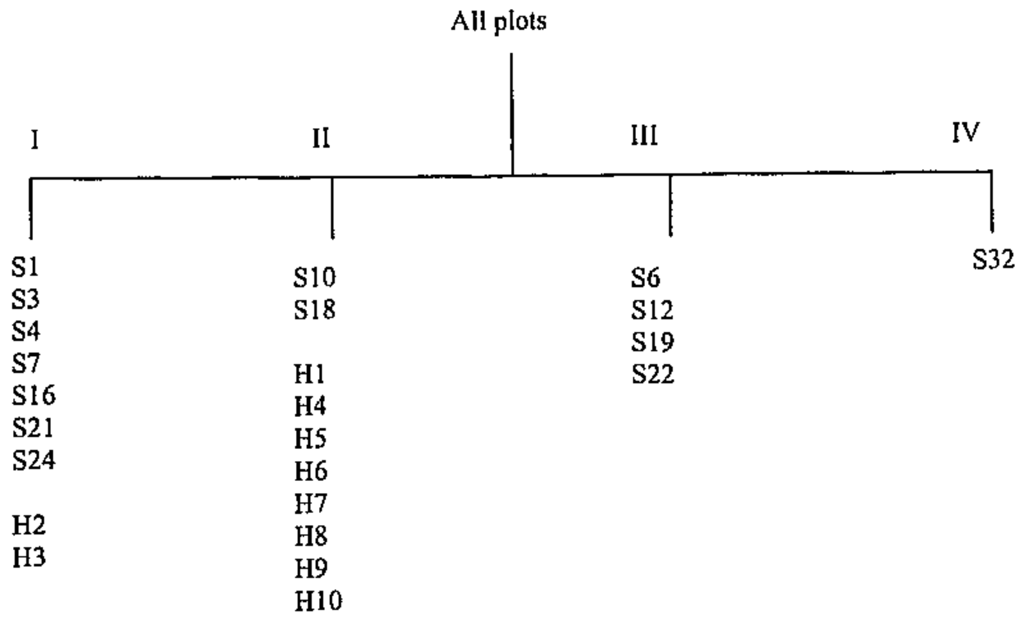


Fig 4; Ordination of the sites according to the habitat variables percent vegetation cover (log transformed) and FHD index.

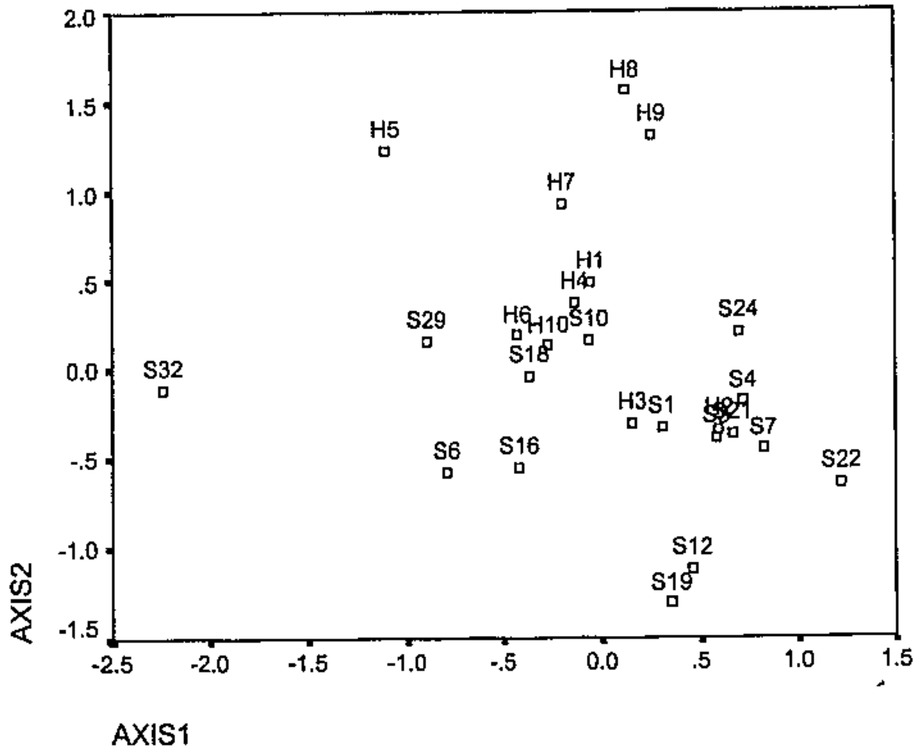


Fig 5; Ordination of sites by the habitat variables percent vegetation cover (not transformed) and FHD

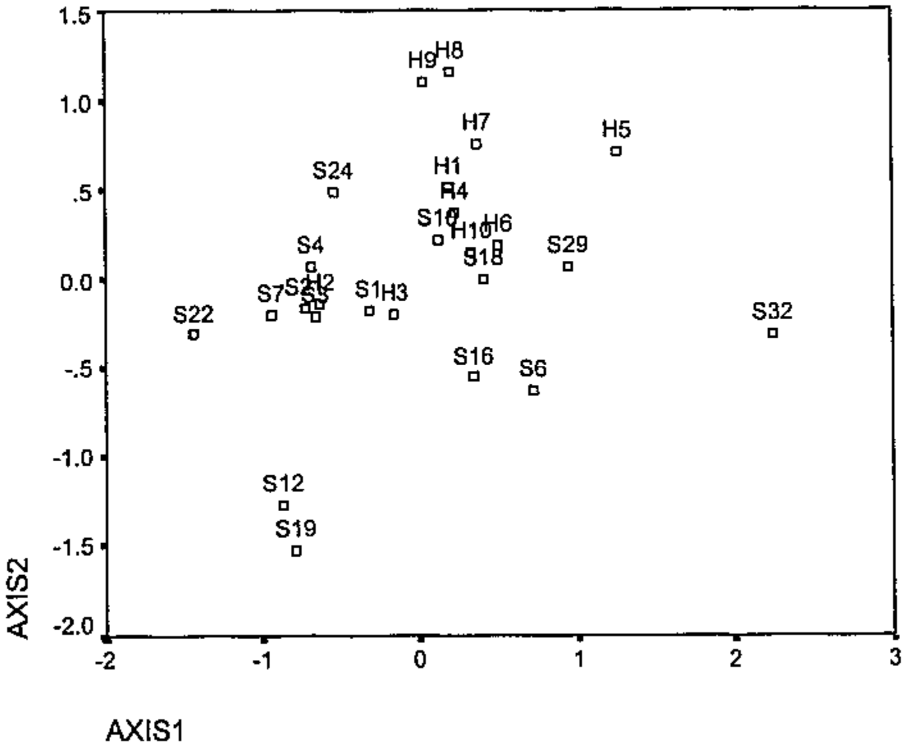
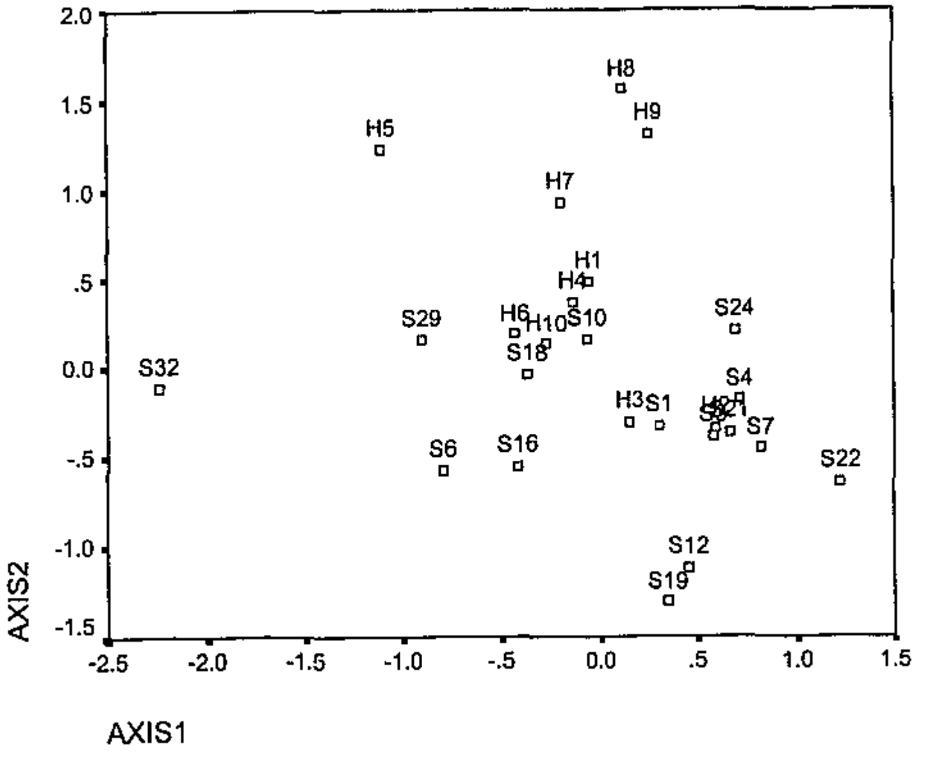


Fig 6; Ordination of the sites according to the habitat variables tree distance, tree height and percent vegetation cover (all log transformed) and FHD.



APPENDIX 5

Table 1; Serventy and Recher transect summary statistics for individual species.

Species densities (birds/m)(multiplied by 1000)						
Species	**Total**	**Section**				
		1	2	3	4	5
Australian Goshawk	2.18	6.62	4.61	0.00	0.00	0.00
Australian Magpie	348.11	874.17	119.82	211.34	123.62	438.10
Australian Raven	238.37	301.32	414.75	273.20	101.55	228.57
Australian Shellduck	9.45	9.93	0.00	0.00	0.00	47.62
Butcher Bird	91.57	69.54	87.56	77.32	119.21	80.95
Black Faced Cuckoo Shrike	18.90	9.93	18.43	10.31	17.66	42.86
Brown Goshawk	3.63	9.93	0.00	0.00	2.21	4.76
Brown Honeyeater	3221.66	307.95	4976.96	4283.51	3306.84	4433.33
Broad Tailed Thornbill	0.73	0.00	0.00	5.15	0.00	0.00
Cockateil	0.73	0.00	0.00	0.00	2.21	0.00
Collared Sparrowhawk	2.18	3.31	0.00	5.15	2.21	0.00
Common Bronzewing Pidgeon	3.63	0.00	0.00	5.15	8.83	0.00
Fan-tailed Cuckoo	0.73	0.00	0.00	0.00	2.21	0.00
Galah	98.84	245.03	41.47	30.93	0.00	223.81
Golden Bronze Cuckoo	4.36	0.00	4.61	5.15	6.62	4.76
Grey Fantail	105.38	16.56	156.68	201.03	99.34	104.76
Horsefields Bronze Cuckoo	5.81	0.00	4.61	25.77	4.42	0.00
Indian Turtledove	18.90	0.00	0.00	5.15	15.45	85.71
Little Falcon	1.45	0.00	0.00	0.00	4.42	0.00
Laughing Kookaburra	112.64	208.60	46.08	134.02	50.77	157.14
Little Wattlebird	9.45	0.00	0.00	0.00	0.00	61.90
Mistletoe birds	1.45	0.00	0.00	0.00	4.42	0.00
Magpie Lark	5.09	19.87	0.00	5.15	0.00	0.00
Pacific Black Duck	0.73	3.31	0.00	0.00	0.00	0.00
Port Lincoln Parrot	836.48	1072.85	589.86	360.82	437.09	2052.38
Rainbow Bee-eater	159.16	0.00	32.26	72.16	381.90	119.05
Rainbow Lorikeet	1579.94	5768.21	317.97	201.03	169.98	1176.19
Red Wattlebird	1432.41	2576.16	764.98	819.59	900.66	2190.48
Rufous Whistler	308.14	19.87	539.17	319.59	417.22	238.10
Spotted Dove	47.24	26.49	9.22	0.00	15.45	228.57
Silver-eye	701.31	221.85	1115.21	835.05	869.76	476.19
Senegal Dove	29.07	29.80	0.00	0.00	17.66	109.52
Singing Honeyeater	255.81	33.11	433.18	216.49	207.51	533.33
Sacred Kingfisher	10.17	0.00	0.00	0.00	4.42	57.14
Spotted Pardalote	0.73	0.00	0.00	0.00	2.21	0.00
Striated Pardalote	171.51	19.87	354.84	489.69	64.02	138.10
Tree Martin	10.90	0.00	0.00	0.00	6.62	57.14
Weebill	628.63	168.87	861.75	680.41	679.91	890.48
White cheeked honeyeater	182.41	0.00	32.26	113.40	421.63	147.62
Western Spinebill	166.42	46.36	520.74	231.96	86.09	85.71
White tailed black cockatoo	23.26	0.00	92.17	0.00	13.25	28.57
Western Warbler	123.55	9.93	281.11	154.64	141.28	57.14
Willie Wagtail	0.73	0.00	0.00	5.15	0.00	0.00
Yellow Rumped Thornbill	42.15	0.00	55.30	118.56	50.77	0.00

Table 2; Habitat characteristics measured in each plot for each section of the Serventy and Recher transect.

	Section 2		Section 3	Section 4					Section 5	
Variable	**Plot 10**	**Plot 9**	**Plot 8**	**Plot 7**	**Plot 6**	**Plot 5**	**Plot 4**	**Plot 3**	**Plot 2**	**Plot 1**
FHD	1.54	1.68	1.64	1.58	1.51	1.36	1.59	1.58	1.67	1.61
Percent Vegetation Cover	71	41	35	48	67	41	65	95	105	61
Tree Height (m)	5.6	3.4	5.7	3.7	3.7	4	3.7	5.3	4.3	5
Tree Distance (m)	7.1	2.7	4.5	4.1	3.6	4.3	3.3	1.5	5.7	4.7
Veldt grass rating	1	1	1	1	1	2	1	1	5	3
Burnt(B)/ Unburnt(U)	B	B	B	B	B	B	B	B	U	U