A Landscape Approach to Determine the Ecological Value of Paddock Trees

Summary Report Years 1 & 2

Prepared for
Land & Water Australia
and the
South Australian Native Vegetation Council

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As always, the full responsibility for errors and omissions lies with the authors.

EXECUTIVE SUMMARY

This project aimed to assess the ecological value of scattered paddock trees at a landscape scale, using two approaches. This first was to undertake an intensive mapping program for two study areas in South Australia, equating to an area of 378,000 hectares, and the second to undertake a field study to assess how birds use paddock trees at various levels of tree cover.

Across two study areas, paddock trees were comprehensively mapped and their extent and cover determined. Paddock trees contribute approximately 15% of total mapped native vegetation cover within the South East study area, and approximately 25% in the Tintinara study area. Paddock tree cover was allocated into patch sizes to determine cohesiveness of cover. The majority of paddock tree patches ie. 85% and 91%, were smaller than 0.06ha (25m x 25m) for the South East and Tintinara study areas respectively. This indicates that for both areas, the majority of paddock trees exist as single trees or small groups of trees in the landscape separated by gaps greater than would have existed prior to European settlement. Within Red Gum (*Eucalyptus camaldulensis*) vegetation types in the South East, the cover provided by paddock trees was over one third of the total cover, and in Tintinara, for 6 of the 12 vegetation types listed, paddock tree cover represents the only remaining vegetation component.

These results indicate that for some vegetation types, regional conservation strategies should include consideration of paddock trees, in order to ensure these vegetation types continue to be represented in the landscapes. One of the most important findings of this study is that paddock trees represent a important and unrecognised component of vegetation cover in both areas, which should not be left unaccounted for in landscape conservation planning. We suggest that cover by paddock trees and small patches should be considered as an additional category when determining regional vegetation targets in regions where paddock tree woodland vegetation types remain.

The digitising method used in this study was compared to the popular SPOT4 Panchromatic remote sensing method to assess mapping differences between the two. A comparison of the two mapping techniques found an underestimate of 40% of tree cover in patches less than 0.06ha (25m x 25m) in the SPOT4 method compared to the digitising method. As these small patches represent the bulk (85%) of the isolated or small clumps of paddock trees, it is important to be aware that they may be missed or under represented by the SPOT4 mapping technique. The SPOT4 method was considered to be generally inadequate in areas where: tree canopies had diameters less than 10m or had thinning canopies caused by dieback or; regions where paddock tree cover was particularly low. Overall the SPOT4 method was less reliable than the digitising method in providing accurate paddock tree canopy cover mapping at a property level for the above mentioned reasons.

A bird study was conducted to determine whether bird use of paddock tree sites changed as the amount of paddock tree cover changed. The study included 49 4ha paddock tree sites on 44 private properties, of differing levels of cover. In addition, there were 26 remnant vegetation sites, defined as dense tree cover, in roadsides, Heritage Agreements, Conservation Parks and private land. Sites for both categories consisted of half Red Gum and half Blue Gum/Pink Gum sites. One third of all diurnal birds previously recorded in the study area were recorded in paddock trees on this field study. 42 of the 45 species recorded in paddock trees were also found in remnant sites. 11 of the species we recorded in paddock trees are listed as declining in other regions of Southern Australia. Results indicate that bird species densities, species richness and species diversity all increased as paddock tree cover increased, where there were low levels of fallen timber on the ground.

Bird species were allocated into functional groups for further analysis. Group1 or woodland dependent species, including some declining species, demonstrated a preference for higher density tree cover sites and remnant vegetation. Group 2 species or canopy feeding birds showed an increase in abundance as tree cover increased. Group 3 species or generalist species demonstrated no relationship with cover and showed no preference for high or low density tree cover sites. Hollow nesters, bark-feeders and foliage-gleaners all showed an increase in abundance as tree cover increased. In addition to this, some groups demonstrated a higher abundance in one vegetation type over another. Birds in group 3 were, on average, more abundant at Red Gum sites than Blue Gum/Pink Gum. Group 2 species, bark-feeders and foliage-gleaners were on average more abundant at Blue Gum/Pink Gum sites than Red Gum sites.

This study indicates that paddock tree cover is a significant factor influencing bird use of paddock trees. Vegetation type also plays a significant role in influencing the abundance of particular species. The results also indicate that each site is unique in relation to the birds it contains and their relative numbers. Bird use of paddock tree habitats is therefore determined by many factors, probably specific to each species particular requirements and to the suitability of the surrounding habitat.

Our results indicate that paddock trees across the landscape are being used by a substantial proportion of the region's birds and by many woodland birds normally associated with remnant patches. Most species using paddock trees were also using nearby remnants, indicating that these trees are probably part of these species' wider habitat. We conclude that bird presence does indicate that a particular tree is being used and the tree is therefore contributing in some way to the habitat value of that environment. In our study area, paddock trees undoubtedly contribute to the overall quality of the matrix for birds, and to the habitat value of the region as a whole.

Clearance together with dieback estimates, place the conservative loss of paddock trees in the South East study area to be 36% over the next 50 years, with 65% of this predicted loss attributed to clearance. In addition to this, tree recruitment was only recorded at one of the paddock tree sites surveyed. This highlights the need for a clear regional strategy for the conservation of paddock trees, as well as investigation and discussion into the contribution of paddock trees to biodiversity conservation and ecological communities as a whole. An expansion of the current tree evaluation system (Cutten and Hodder, 2002) to include a tree's value at the local landscape scale, may result in greater restrictions for clearance of some trees. Similarly, results indicating the significance of cover and vegetation type could be used to provide guidelines for more strategic management and recruitment of paddock trees for long term conservation. Results could also be used to assist in further developing guidelines for placement and design of revegetation areas in paddock tree areas.

1 INTRODUCTION

1.1 Background

Across Australia, the words paddock, scattered or isolated trees, broadly refer to the remaining native trees left standing across land that is predominantly used for agriculture.

The South Australian definition is: "Naturally occurring indigenous trees … that occur over little or no native understorey, and with a spatial arrangement varying from that considered to be close to the original distribution (pre-European settlement)…" (Cutten and Hodder, 2002 p4) . The New South Wales definition is simply, " trees around which the other components of a native vegetation community have been removed." (Land & Water Conservation p1 1999). Recent changes to native vegetation clearance legislation and to biodiversity conservation policy within Australia are attempting to include the whole of the agricultural landscape in conservation planning.

Paddock trees have social and amenity value, farm production and economic value, and ecological value. Research indicates that paddock trees are likely to be important to sustain a range of ecological functions. Trees in paddocks contribute to regional ecosystem services, reducing ground-level wind velocities, fire intensity, and potential pasture acidification (Reid and Landsberg, 1999), as well as being contributing to soil conservation (Wilson, In press). For invertebrate species paddock trees provide important habitat including feeding, shelter and breeding (Cutten and Hodder, 2002). Paddock trees and small remnants also appear to influence invertebrate abundance and diversity (Majer et al., 2000), with individual trees potentially supporting unique combinations of invertebrate species (Hill et al., 1997). Research has demonstrated that bats show a high usage of paddock trees in agricultural landscapes (Lumsden et al., 1995;Law et al., 1999;Law et al., 2000), and many birds use a wide range of sites, persisting even in highly fragmented and degraded habitats (Ford and Barrett, 1995;Law and Dickman, 1998;Fischer and Lindenmayer, 2002a). Many mammal and bird species, including some conservation rated species, rely on paddock trees for nesting and roosting hollows. In south-eastern South Australia and western Victoria, single paddock trees provide habitat for both nationally endangered Red-Tailed Black-Cockatoo and the Swift Parrot (Croft et al., 1999).

There is a need for further research to be undertaken in order to understand the wider landscape value of paddock trees. According to Ford et al., (1995) the diversity of birds in the landscape is related to the diversity of other groups of organisms, so that the health of the bird community indicates the health of the ecosystem. The observation that many birds move across the landscape can assist in explaining the way in which the various components of the landscape are inter-related (Fisher, 2000). It is therefore, more realistic to view the landscape as variegated, consisting of a mosaic of patches of differing quality (McIntyre and Barrett, 1992). Many species of birds see natural habitats as consisting of patches that vary greatly in quality and even in a highly fragmented and degraded habitat, birds can use a wide range of sites other than those of the best quality (Ford and Barrett, 1995). Fahrig (2001) suggests that while reproductive rate has the largest potential effect on the extinction threshold for fauna populations, matrix quality was more important than fragmentation (Fahrig, 2001). Habitat patches are parts of the landscape mosaic and the presence of a species in a patch may be a function not only of patch size and isolation, but also of the neighbouring habitat (Andrén, 1994). Conservation strategies should consider the quality of the whole landscape including the matrix (Fahrig, 2001), and this includes paddock trees.

Birds are highly mobile, easily observable, and have been well documented as major users of paddock trees (Fischer and Lindenmayer, 2002a;Orr, 2003;Collard, 1999;Paton et al., 1999;Cutten and Hodder, 2002). However, detailed data on the use of paddock trees by entire bird communities in Australia are almost non-existent (Fischer and Lindenmayer, 2002a). In the South East of SA, paddock trees are broadly understood to provide important habitat for birds, however to date, this understanding has been largely associated with characteristics of individual trees (Cutten and Hodder, 2002). Most bird species use landscapes at a functional scale of tens to hundreds of hectares (Cale and Hobbs, 1994), while groups such as honeyeaters regularly move distances of 10-100km in search of food within the Mt Lofty region in SA (Paton et al., In Prep).

Birds are the key taxa considered in the SA clearance assessment tree scoring system and have considerable bearing on how well a tree scores and whether consent for tree clearance is given (Cutten and Hodder, 2002). Woodland birds are in decline in other areas of the State (Paton et al., 1994) and Australia (Reid, 1999;Fisher, 2000) and are therefore a group at risk through habitat reduction and deterioration. Half of Australia's terrestrial avifauna is predicted to be lost over the next century, if management practices remain unchanged. (Recher, 1999). Past studies have established a relationship with bird use and individual tree characteristics (Fischer and Lindenmayer, 2002a;Orr, 2003;Paton and Eldridge, 1994), and to distances from larger remnants (Fischer and Lindenmayer, 2002a;Orr, 2003;Law et al., 2000), however, no relationship between bird use and paddock tree cover has been established. Further research is needed in order to understand the wider landscape value of paddock trees, particularly in areas where tree clearance is occurring.

Despite the potential benefits of paddock trees, their long term survival is threatened by clearance and dieback, predominantly due to the adverse impacts of agricultural farming practices on tree health, coupled with a lack of recruitment. Clearance pressure is largely the result of agricultural intensification and development. In South Australia, the Native Vegetation Council (NVC) may approve the clearance of paddock trees subject to the Native Vegetation Act (1991), providing that such clearance is not significantly at variance with principles detailed in Schedule 1 of the Act. Applications are assessed on a property–by–property basis. The method provides for assessment consistency across applications, but does not facilitate an assessment of trees at a landscape scale. Industry representatives have similarly expressed the need for a more rapid decision-making process, and a clear idea before land purchase of areas where biodiversity values may limit the likelihood of clearance consent (Government of South Australia, 2000).

A condition of clearance approval in South Australia is a requirement for a net biodiversity gain. Such gain is generally achieved by requiring the landholder to permanently conserve intact vegetation (often protected by a Heritage Agreement), to regenerate degraded vegetation, or to replant a cleared area. These "set-aside areas" are located as close as practical to the cleared vegetation and planted using local species, to maximise linkages with existing blocks. The locations of set-aside areas are subject to negotiation with the landholder. Recent changes to the legislation now enable a landholder to fund an off-property set-aside area in accordance with regional priorities. It is anticipated that the results of this project will assist with defining a set of guidelines for identifying and planning set-aside areas that maximise benefits for paddock tree recruitment at a landscape level. In addition to this, regional conservation and natural resource management strategies require a landscape perspective of where paddock trees make important contributions to biodiversity conservation, in order to determine the most appropriate sites to allocate resources for a biodiversity gain.

1.2 Overall Objectives

This project aims to identify the ecological value of paddock trees from a landscape perspective. This involves understanding both their extent and distribution across the landscape as well as the relationship of canopy cover or tree density to habitat value for regional fauna. Its broad objectives are:

1. To map and analyse, using GIS techniques, spatial patterns of paddock trees and currently unmapped small overstorey remnants (<1 ha) within two agricultural systems in South Australia.
2. To identify critical zones across the landscape where paddock trees and clumps of trees in cleared agricultural land make an important contribution to biodiversity conservation. Based on a practical spatial model, using mapped tree data, other existing datasets, and knowledge of the habitat requirements of regional bird species (based on field study results).
3. To identify regions at the landscape scale where approval for vegetation clearance is considered to be unlikely.
4. To develop guidelines to assist other regions in evaluating the ecological value of paddock trees.
5. To investigate the contribution of paddock trees and small remnants to native vegetation cover targets (i.e. James and Saunders 2001) within two regions of agricultural South Australia with plant communities typical in structure to vegetation found within the Murray-Darling Basin.
6. To develop strategies for identifying revegetation areas at the landscape scale.

The emphasis of the project has been to capture baseline data, both for mapping and for the landscape scale ecological value assessment, in order to undertake analyses that are clearly based on real data for the study areas. Guidelines for what data to collect and methods for how best to collect them were based on assessments of pre-existing theory and research on paddock trees in Australia.

1.3 Specific Objectives of the Mapping

- To refine a method to accurately map locations of paddock trees and small clumps under 1ha, using ortho-rectified aerial photography, including an estimation of mapping error.
- To map paddock trees across two study areas with distinctly different vegetation structural groups
- To determine the contribution of paddock trees to overall extant vegetation cover and to individual plant communities
- To develop a mapping method for broadly categorising paddock trees into cover categories for use in assessing conservation, habitat and restoration potential.
- To compare the digitising method with more common remote sensing methods to determine how transferable the method would be for interstate use.

1.4 Specific Objectives of the Bird Survey

- To determine what bird species are using paddock trees in farmland in the south east study area
- To identify how bird species richness varies in nearby native vegetation patches of the same vegetation type compared to that in paddock trees
- To determine whether bird species diversity, species richness and estimated densities changes as tree cover increases
- To determine whether the presence and/or abundance of different functional groups of birds is affected as tree cover increases
- To determine what site characteristics (e.g. tree cover, presence of timber, litter) influence bird species diversity, species richness and estimated densities
- To identify what landscape characteristics (e.g. amount of surrounding cover over different distances, distance to nearest vegetation patch) influence bird species diversity, species richness and estimated densities

1.5 Study areas

Two study areas were selected for this project (Figure 1). Extensive vegetation mapping datasets exist for both. Extant vegetation cover and floristics have been mapped at 1:40,000 (Heard and Channon, 1997;Kinnear and Gillen, 1999). Pre-European vegetation mapping at 1:50,000 exists for the both study areas (Croft, 1999;Croft, In prep).

The first study area covering approximately 270,000 ha is located in the South East of South Australia, with 9.2% extant native vegetation cover (this excludes paddock trees and patches smaller than one hectare). Forest and woodland communities characteristically dominate the study area across floodplains and calcarenite dune ridges. Intervening poorly drained areas also contain wet sedgelands and herblands. Stringbark (*E. arenaceae/baxteri*) woodlands dominate vegetation blocks along sand ridges. Of areas that have been classified as pre-European woodland vegetation, 65% has been classified as woodland, with 19% open forest, with the remaining 5% low woodland. Red Gum (*E. camaldulensis var. camaldulensis*) woodland is estimated to have occupied approximately 38% of the study area at the time of European settlement. Several woodland communities have been given a high conservation rating (endangered, vulnerable, rare) owing to extensive clearance and low representation within regional reserves (Croft et al., 1999).

Paddock trees of Red Gum, Blue Gum (*E. leucoxylon)*, Pink Gum (*E. fasciculosa)* and Manna Gum (*E. viminalis ssp. cygnetensis*) remain throughout the heavily cleared, fertile, agricultural areas. The South East of SA is undergoing agricultural intensification for vineyard, centre-pivot irrigation, and forestry development. Based on the extant vegetation mapping, the study area has 9.4% vegetation cover remaining, with much modification and many threats, roughly equivalent to a fragmented, or even relictual landscape (McIntyre and Hobbs, 1999).

The broader South East region within which the study area lies is important for that state with regard to mammal and bird species (Croft et al., 1999). At the time of European settlement it contained 53% of all the State's mammal species and 77% of bird species. Today, of the 54 mammal species once found, 16 are extinct, 6 are endangered, 4 are vulnerable and 11 are rare, in other words, 68% have a high conservation rating (Croft et al., 1999). It is the most diverse region in the State for bat species, with 16 confirmed species, although the distribution, status, habitats and life history of the bat fauna of the region are poorly known due to limited survey work (Croft and Carpenter, Unpublished). The mammal species potentially significant to the study area for this project and partly reliant on paddock trees are the Sugar glider (*Petaurus breviceps*) (SA rare), Brush-tailed Phascogale (*Phascogale tapoatafa*) (SA endangered), along with numerous bat species. Of the 275 bird species once found in the region, 7 are extinct, 9 are endangered, 30 are vulnerable, 2 indeterminate, 23 rare and 49 uncommon, or in other words, 44% have a high conservation rating (Croft et al., 1999). The South East study are is well known as a feeding and nesting area for the nationally endangered Red-tailed Black Cockatoo (*Calyptorhynchus banksii graptogyne*) and the State vulnerable Yellow-tailed Black Cockatoo (*Calyptorhynchus funereus*) (Croft et al., 1999).

The second study area is located between Tintinara and Coonalypn and lies on the southern margins of the Murray Darling Basin. Technically it is located within the Murray Mallee region of the State (Kahrimanis et al., 2001), however it is often considered as part of the upper South East region. The study area covers approximately 108,000 ha, with 8.8% extant native vegetation cover (this excludes paddock trees and patches smaller than one hectare). The original vegetation of the region consisted of a mixture of Blue Gum and Pink Gum woodlands (32%), various mallee communities (45%) and Shrublands (17%). The extant or remaining vegetation now consists of large remnant patches of almost exclusively of mallee, small mallee clumps in paddocks, and paddock paddock trees, predominantly consisting of Blue and Pink Gum. The Tintinara region is increasingly affected by dryland salinity and is a study site for a National Action Plan salinity mapping project (Primary Industries and Resources SA) and related vegetation condition assessment projects.

Listed in the Biodiversity Plan for the SA Murray-Darling Basin, the study area is called the Coonalpyn District Fragmented Habitat Area (Kahrimanis et al., 2001). This area contains a number of conservation rated bird species including the Yellow-tailed Black Cockatoo. Few mammal species that use paddock trees for habitat exist in the study area, however the Lesser Long-eared Bat and Southern Forest Bat are listed for the area and would use paddock trees for feeding and roosting (Biological Databases of South Australia).

Both study areas have vegetation structurally typical of other parts of the Murray-Darling Basin in Victoria and NSW for both remnant vegetation and paddock tree components. Paddock tree health in both study areas is a major issue, with the Tintinara study area of particular concern (Paton et al., 1999). Unauthorised vegetation clearance is an issue in both study areas.

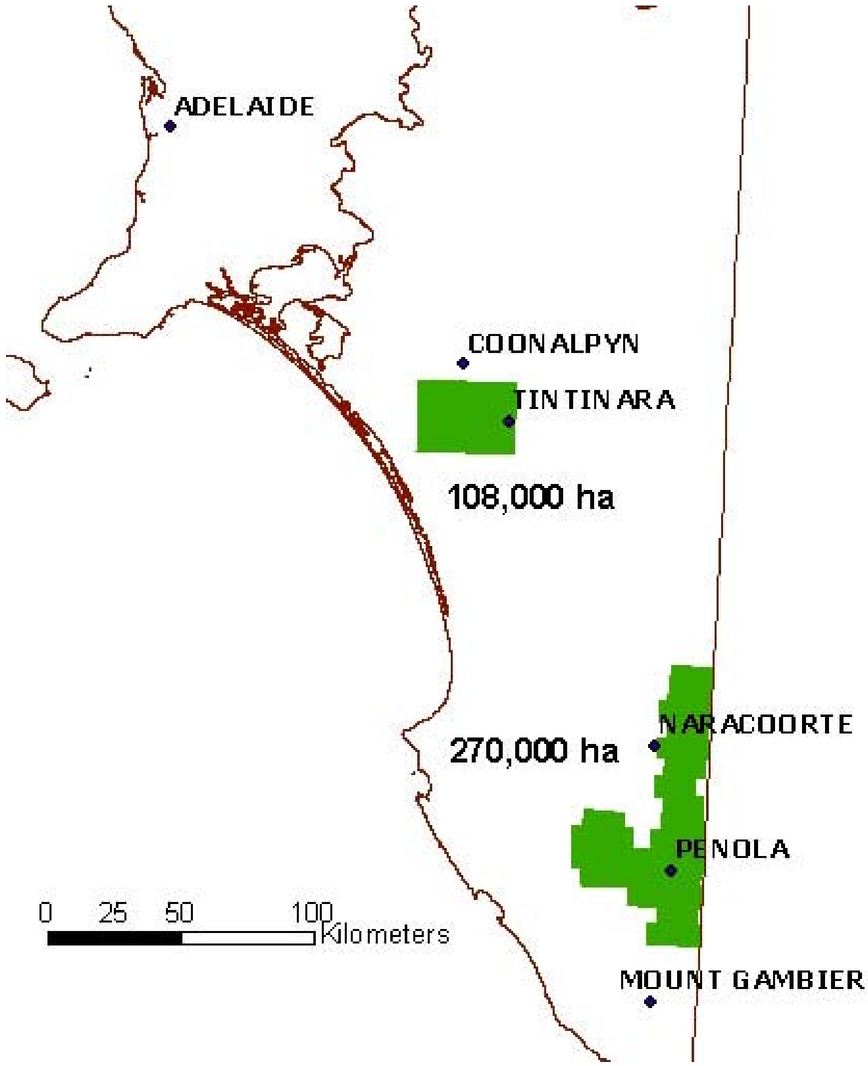


Figure 1 Location of study areas

2 BROAD CONTEXT

This study is concerned with the remnant paddock trees of the Australian agricultural landscape. More specifically, it considers these trees as part of former woodland and mallee communities that have been variously altered by grazing and mixed cropping. The goal is to refine our understanding of the ecological value of these trees at the landscape scale and the implications of this for their management.

2.1 Mapping

2.1.1 Density and cover of paddock trees

Vegetation cover provided by remaining vegetation is a standard reporting measure in Australia and elsewhere (e.g.Croft et al., 1999;Kahrimanis et al., 2001;National Land and Water Resources Audit, 2001). Modelling has indicated threshold percentages of vegetation cover below which patch size and isolation have a significant effect on fauna (Andrén, 1994). Remaining regional percentage cover of native vegetation has been used in the evaluation of native vegetation for clearance (e.g. Cutten and Hodder, 2002), and as a surrogate for policy targets in planning (eg. James and Saunders, 2001;Croft et al., 1999;Kahrimanis et al., 2001).

Native vegetation mapping within the agricultural regions of Australia exists at a variety of scales. With the exception of mapping in the ACT, the majority of vegetation mapping in agricultural regions of Australia is based on scales of 1:50,000 to 1:100,000 (National Land and Water Resources Audit, 2001). At these scales, the minimum mappable area of vegetation typically ranges from one to ten hectares. Paddock trees and vegetation blocks less than this threshold, are generally unmapped across Australia (Reid and Landsberg, 1999;Gibbons and Boak, in press) Paddock trees have been estimated however, to cover 20 million hectares over the temperate woodland areas of Australia (Reid and Landsberg, 1999).

2.1.1.1 Spatial contribution of paddock trees

The spatial contribution of individual trees in the landscape has been measured in two main ways: as a relative area measure (percentage cover) (Gibbons and Boak, in press) and as a stem density (trees per hectare) (Bennett et al., 1994;Guevara et al., 1998;van der Ree, 2001). Both of these measures broadly reflect the spatial distribution of trees and so are often used in describing studies that have examined the relationship between paddock tree abundance and faunal ecology. For the purposes of describing the spatial contribution of paddock trees at the landscape scale however, knowing the actual cover of paddock trees over a given area is considered more useful. The are three main reasons for this. Firstly, in estimating the stem density of paddock trees from aerial photography, error does occur (Guevara et al., 1998). Secondly, the relationship between canopy cover and stem density differs between species, and hence, stem density does not bear a uniformly accurate relationship to cover. Lastly, the ability to map paddock trees as cover using different techniques ensures a greater transferability to other regions of the information regardless of the specific mapping method used.

Paddock trees have been estimated to cover 20 million hectares over the temperate woodland areas of Australia (Reid and Landsberg, 1999). Only two studies in Australia have attempted to quantify the actual cover represented by paddock trees in the landscape. In the Riverina Highlands of New South Wales, with 12% extant native vegetation cover, tree cover over an area of 30,000hectares was mapped using remote sensing methods (Gibbons and Boak, in press). In the south east of South Australia, with 9.4% extant native vegetation cover, approximately 200,000 paddock trees over an area of 270,000 hectares were individually mapped from ortho-rectified aerial photography (Bickerton et al., 2002). In both these studies paddock trees were defined as isolated trees, small patches and woodland remnants up to 1hectare in size (Gibbons and Boak, in press). In the New South Wales study, the minimum size of an individually mapped tree (and therefore of a patch), was canopy cover greater than or equal to 100m m² and greater than 20m from adjacent woody vegetation. In the South Australian study the minimum size was greater than or equal to 25m m² and greater than 5m from adjacent woody vegetation.

Patches less than 0.5 hectares in size in both studies are particularly important as these represent all of the isolated paddock trees and small patches of paddock trees. In these studies they were found to contribute 26% and 13% respectively of the total extant native vegetation cover. Both studies found that certain plant communities were more represented by these small patches than others. In New South Wales, 41% of extant woodland communities of the foothills and plains, and in South Australia, 33% of extant Red Gum Woodlands, existed as paddock trees in patch sizes smaller than 0.5 hectares. This is particularly important for both these communities in that less than 3.4%, and 5.4% respectively, of their original extent remains in remnant patches larger than 1hectare (Gibbons and Boak, in press;Bickerton et al., 2002). A slightly different version of tree cover density mapping has been completed for the state of Victoria. This mapping classifies 'scattered woodland' as ‘sparse’ using a 'clustering' process that generalizes the original tree data derived from satellite imagery into broader mapped polygons. Polygons smaller than 1 hectare are removed (Department of Sustainability and Environment, 2003). A spatial analysis of the paddock tree component of this data has been undertaken as part of this project, and a comparison with the mapping discussed in this report can be found in Section 5.

2.2 Value of Paddock Trees

Paddock trees have three broad areas of value. These are their social and amenity value, their farm production or economic value, and their ecological or habitat value.

2.2.1 Social and Amenity Value

Hard to quantify but significant is the social and amenity value of paddock trees to both landowners and the wider community. Reid and Landsberg (1999) point out that across the southern Australian sheep belt, survival of trees has been of concern since European settlement. They suggest that dieback causes greater concern among rural communities than most other environmental issues, probably due to the visual impact of dying paddock trees in paddocks. The value of trees for their contribution to an overall landscape picture for both locals and tourists and for promotion of regional tourism could therefore be assumed to be high. In the South Australian tree clearance legislation, trees may be refused for clearance if their amenity value is deemed significant (Cutten and Hodder, 2002). From a cultural heritage perspective, the value of remaining trees increases as those surrounding them are removed. Common wildlife species associated with paddock trees also contribute to their amenity value and Loyn and Middleton (1981) perhaps best summarise this when describing these species as a highly conspicuous and an important aesthetic component of Australia’s rural landscape.

2.2.2 Farm Production Value

The presence of paddock trees in farmland has a beneficial effect on overall land conservation and they contribute to sustainable land use. Their replacement cost has been estimated at $20 billion (Reid and Landsberg, 1999). Trees have a role in soil conservation through their positive affect on soil properties, soil retention, and water and nutrient recycling. Along with these they provide protection for stock.

Wilson (In press) examined soil properties around both stocked and de-stocked paddock trees and found that soil pH, carbon, nitrogen and extractable phosphorous content all decreased significantly with increasing distance from trees. This study concluded that trees have an overall beneficial effect on soil properties and are valuable for soil conservation in grazing systems. In addition to this paddock trees support a high diversity of soil biota in grazed landscapes, significant for conservation of soil properties (Chilcott et al., 1997). Nobel and Randall (1999, cited in Reid and Landsberg 1999) concluded that while some species were more effective than others, trees could help to reduce soil acidification.

According to Bird (1990) in the higher rainfall areas of southern Australia, 10% of the farm can be profitably devoted to trees. While in semi-arid and dry temperate areas, planting of 5% of land to shelter could reduce wind speeds by 30-50% and soil loss by 80% (Bird et al., 1992). They also note that in Australia there is a lack of good data examining the effects of tree species and spacing on pasture growth (Bird et al., 1992). Similarly, the hydrological role of large isolated trees in agricultural areas of Australia has not been examined with any rigor by field studies (Celebrezze et al., 1996). Trees present in large enough numbers prevent increased surface run-off and therefore dryland salinisation, caused by rising saline groundwater levels (Paton et al., 1999).

Trees positively influence animal production by reducing livestock maintenance requirements through provision of shelter and associated decreased energy expenditure (Chilcott et al., 1997). Paddock trees may enhance pasture growth, by providing light shade, nutrient distribution via tree litter and frost protection (Reid and Landsberg, 1999). In addition to these, paddock trees have a wider economic benefit including their value for honey production, firewood and as seed sources for revegetation activities (Reid and Landsberg, 1999).

In an economic survey (S Walpole pers com cited in Reid and Landsberg 1999) found that in the Liverpool Plains of New South Wales, the highest farm incomes corresponded to farms with approximately 30% tree cover, even though the specific ecological processes behind this were not described.

2.2.3 *Ecological Value*

With the removal of understorey and thinning of the original canopy, paddock trees are quite different to intact remnant native vegetation in an ecosystem sense. Despite this they complement and enhance these intact areas (Majer and Recher, 2000). Paddock trees provide important habitat both at the micro level with regards to direct and indirect effects, at the individual tree level, with regards to invertebrates, and as local habitat over a wider area for vertebrate species. The way in which tree resources are used requires they be assessed at both the individual tree and the landscape level.

Much of the theory and research around native vegetation and its use by fauna has focussed on larger remnants of native vegetation. While patch size and integrity is considered to be the most significant factor for long term survival of many fauna species (Diamond, 1975;Haila et al., 1993), habitat fragmentation and the effect of isolation is not considered the same for all species (Bennett, 1990;Saunders et al., 1991). McIntyre and Barrett (1992) suggest that some species are less susceptible to fragmentation than others, and that for these species potential habitat forms a continuum across the landscape. The agricultural landscape or matrix between remnant patches is therefore not necessarily hostile to all species.

Paddock trees represent habitat for many fauna species within this continuum, whether on a part or full time basis, and they provide connectivity between habitat areas. While paddock trees have the potential therefore to provide habitat resources, this doesn't guarantee their use. The studies mentioned below have tried to identify the factors that determine whether they will be used and by which taxa.

For invertebrate species paddock trees provide important habitat including feeding, shelter and breeding (Cutten and Hodder, 2002). Majer and Recher (2000) studied invertebrates in isolated trees and found they were able to support high invertebrate populations. They also found arthropods were remarkably abundant, as was a diverse array of beetle species, on isolated trees (Majer et al., 2000). Hill et al., (1997), conducted a study of ground invertebrates in 20 individual paddock trees at 5 different sites in the Mount Lofty Ranges of South Australia. One set of north, south, east and west facing pitfall traps were placed per tree at 1m, 3.5m, 8m and 15m from the trunk. Over 2600 ground invertebrate taxa were recorded in 72 pitfall traps from just 8 trees. The highest number of taxa and the highest number of unique taxa were found in pitfalls set 1m from the base of the tree. At each distance there were at least 40 taxa present, of which 10-20 species were unique to that distance. At least 48 invertebrate taxa were found under the tree canopy (i.e. up to 8m from the trunk), that were not found outside (i.e.15m from the trunk). Even based on limited sampling, the litter fauna associated with individual trees was diverse and potentially unique to each tree (Hill et al., 1997). From this they concluded that some invertebrates may now have restricted distributions, and that individual trees may support unique combinations of invertebrate species that are now isolated from other populations. If suites of species, such as invertebrates, are confined to single trees then removal of those trees results in a loss of biodiversity (Hill et al., 1997).

For vertebrate species, paddock trees provide resources such as nectar, pollen, fruit, seed, foliage, bark, roots, litter and perches (Cutten and Hodder, 2002). Many paddock trees contain cavities or hollows, which support nearly 400 species of Australian vertebrates that use them for dens, roosts or nests (Reid and Landsberg, 1999).

Paddock trees represent important habitat for insectivorous bats. Results of two Australian studies recorded 13 and 21 species respectively, flying in close proximity to paddock trees (Lumsden et al., 1995;Law and Anderson, 2000). Within the agricultural regions of SA, 15 species of bats are known to use paddock trees for foraging and roosting (Cutten and Hodder, 2002). Insectivorous bats have two key habitat requirements for living in the rural environment, these are roosting sites for shelter during the day and for periods of winter inactivity, and foraging areas for feeding (Lumsden et al., 1995), and both of these are provided by paddock trees. All insectivorous bats require tree hollows or equivalent cavities, for roosting and nesting (Lumsden et al., 1995).

The significance of paddock trees for woodland birds is well recognised. Within South Australia agricultural regions, 125 native bird species are known to use paddock trees (Cutten and Hodder, 2002). Specific studies have recorded 44 bird species using paddock trees in New South Wales (Fischer and Lindenmayer, 2002a) and 34 bird species using paddock trees in the south east of South Australia (Collard, 2000). These birds may use paddock trees for feeding, either on insects and or nectar, for nesting, either in built nests or hollows, and for shelter. A study in South Australia found that trees were not used evenly across the landscape, and results indicated that some trees were preferred for use by a greater number and wider range of birds (Orr, 2003). In addition to this, birds were found more commonly in trees with lower foliage (Orr, 2003). This study also found that there was a fairly strong relationship between abundance of hollows of varying sizes and the presence of birds in paddock trees (Orr, 2003).

A Victorian study sampled trees across all patch types and found that most large trees on privately grazed land contained hollows, while large patches on public land contained few hollow bearing trees (Bennett et al., 1994). In addition to this, the study found that large trees comprised only 8% of all trees, but they represented 52% of all trees with hollows. This study concluded that the availability of new hollows in the next century and beyond would be directly influenced by whether successful tree recruitment occurs in farming areas. This is further supported by evidence that trees containing small hollows suitable for use by fauna are generally greater than 150 to 200 years old, with large hollows taking 220 to 280 years to form (Gibbons et al., 2000). The importance of these hollow bearing trees in relation to clearance is supported by figures collated in South Australia. In 770 hollow bearing paddock trees assessed for clearance, a combined 298 large, 822 medium and 983 small hollows were counted (Cutten and Hodder, 2002). The presence of hollows in paddock trees is a major factor in determining whether a tree will be consented for clearance in South Australia (Cutten and Hodder, 2002).

A study by Loyn and Middleton (1981) in Victoria, looked at bird use of pasture, paddock trees and remnant woodland. They concluded that eucalypts including paddock trees were an essential part of the habitat for 25 birds and 1 mammal. Further to this, a total of 69 birds and 4 mammals (plus bats) needed eucalypts to survive in farmland and that all would suffer the effects of habitat loss were these trees to extensively decline. Fischer and Lindenmayer (2002a) found that many of the birds detected in woodland patches were also common in paddock trees. They also looked at arrival and departure patterns of birds using paddock trees and concluded that paddock trees were being used as stepping stones, most pronounced in the nectarivores, and these trees had the potential to enhance landscape connectivity (Fischer and Lindenmayer, 2002b). Hill et al. (1997) observed that 40 bird species and 2 arboreal mammals regularly used and moved between paddock trees in the Mount Lofty Ranges in South Australia. Flocks of honeyeaters have been documented using lines of trees as flyways, even when the trees are widely spaced (Loyn and Middleton, 1981). Orr (2003) found that based on patterns of bird movement to and from paddock trees, woodland patches appeared to act as centres of bird activity in the landscape and paddock trees as spokes.

Bennett and Ford (1997) found that the best predictor of species richness for woodland birds in the landscape was the amount of tree cover, and the degree of woodland fragmentation. This study determined a minimum of 10% tree cover was required at the landscape scale. While paddock tree cover was not included in this cover estimate, their presence in the landscape was noted, indicating that they contribute to the overall required cover and to the lessening of habitat fragmentation. Similarly, rural landscapes with 10% tree cover were found to be more likely to support populations of insectivorous bats than those without trees (Lumsden et al., 1994). The presence of paddock trees in these landscapes has been difficult to spatially quantify, leaving conclusions about how they contribute in the habitat continuum unresolved.

One of the most difficult to measure but suspected results of paddock tree clearance is the changes to local bird communities using all vegetation in the local landscape for habitat. In a study conducted in the south east of South Australia, bird communities were sampled before and after the clearance of 900 paddock Pink and Manna Gums (Collard, 1999). According to this study, the removal of the trees significantly modified bird communities in both the remaining paddock trees and in the remaining vegetation surrounding them.

Health has a significant effect on the proportion of habitat services an individual paddock tree is able to provide to wildlife. Paton and Eldridge (1994) demonstrated that the average number of birds per tree was higher for healthy trees, possibly a reflection of the higher canopy volume. They also demonstrated that birds forage less frequently in trees in poor condition, that these trees support different bird species to healthier trees, and that the birds using trees in better condition were more beneficial to these trees than those using trees in poor health. They concluded that the numbers and diversity of birds using rural areas would decline even if all tree clearance stopped, if loss of vigour in paddock trees continued (Paton and Eldridge, 1994;Paton et al., 1999).

Eucalypts vary in the amount of nectar resources they provide from one year to the next (Bennett and Wilson, 1999). Along with this the size of the tree may determine how much and how often it can provide feeding habitat for nectar dependent birds (Bennett and Wilson, 1999). The implications of these nectar fluctuations in paddock trees means, that accurately predicting across the entire landscape which trees will be a resource at any one time, is difficult. Leaving as many paddock trees in the landscape as possible is therefore a necessary strategy for landscape scale availability of these resources over time.

The role of tree isolation and its effect on habitat use by different taxa is largely unknown. Paton and Eldridge (1994) found that numbers and types of birds changed as the density of trees and understorey was reduced and as tree condition declined. Law et al. (2000) found that isolated trees were visited by as many bird species as trees in patches or remnants, although the species themselves differed. In contrast a study on insectivorous bats showed no significant difference in capture success between large and small remnants or scattered paddock trees, as they appeared to be tolerant to fragmentation due to their mobility and social organisation (Lumsden et al., 1995).

Similarly, the significance of distance to vegetation patches is not well understood. There is theoretical evidence to suggest, that within the landscape, the distance of a paddock tree to the nearest woodland patch may affect on its role as habitat for vertebrate fauna (Turner et al., 1991;Fahrig and Merriam, 1994;Wiens, 1997). At present however, there is little evidence to indicate that distance from a woodland patch significantly affects the fauna diversity supported by paddock trees. The size and distance of the nearest vegetation patch may be of more importance than distance alone. A distance less than 797 m to the nearest State Forest significantly affected the likelihood of observing a nocturnal mammal in a paddock tree, however distance to nearest remnant (less than 10 hectares) was not a condition for a high probability of a nocturnal animal occupying a hollow (Law et al., 2000).

In a study of bird use of paddock trees, no significant relationship could be detected between site species richness of birds and the distance to nearest woodland patch (Fischer and Lindenmayer, 2002a). Trees isolated by more than 90m from corridors of native vegetation showed a higher probability of occupation than less isolated trees (Law et al., 2000). This may indicate that the further animals traveled from a woodland corridor, the fewer trees they had to choose from. Orr (2003) examined bird movements in paddock trees up to 500m from woodland patches and found that all trees were used, but that abundance and species richness changed with distance. These relationships were however not linear, and the study concluded that no single tree or landscape parameter strongly determined the presence of birds in trees (Orr, 2003).

2.2.4 *Genetic Implications of Paddock Tree Loss*

There are two key genetic consequences of fragmentation and degradation (Celebrezze et al., 1996). These are the loss of genetic resources and diversity when plants are removed, and the likely change of pollinator behavior and hence patterns of gene flow due to changes in the density and spatial distribution of plants. Addressing the viability of paddock trees in paddocks for recruitment and as seed sources for revegetation requires information about the genetic effects that clearance and isolation has on remaining trees. The genetic affects that result from tree clearance, changes in tree spacing between remaining trees, and understorey removal, are largely unknown. Genetic studies are important in that they can provide guidelines on how recruitment will be impacted by existing genetics, and how recruitment and revegetation in paddocks will then impact upon future genetics. Issues such as maintenance of gene flows, seedling fitness and seed set are important for long term management of paddock trees in paddocks.

The type of pollinator i.e. insects or nectarivorous birds will influence the way in which pollination processes are affected by isolation. The insect-pollinators of *Eucalyptus albens* for example, do not cross cleared areas greater than 250m (Prober and Brown, 1994). In contrast to this, individually tagged honeyeaters and lorikeets have been detected moving more than a kilometre within a few hours and hence bird-pollinated eucalypts may not be as readily isolated by vegetation clearance as insect-pollinated species (Paton et al., 2003;Celebrezze et al., 1996).

In studies focussing on *Acacia acinacea,* early findings indicate that small remnants near to a larger source of genetic material may have better seedling survival rates than those of more isolated remnants (L. Broadhurst in Hall 2003). Another factor influencing recruitment is the amount of seed production. It may be likely that there is a decrease in seed production and therefore recruitment as pollination distances increase (Prober and Brown, 1994). The conversion of flowers to seeds may also be low in paddock trees. Self-pollinated ovules have been demonstrated in *E. globulus* to have less total seeds per capsule and lower seed viability (Hardner and Potts, 1994). Self-pollination was demonstrated to have no effect on germination, however there was a significant effect on survival over 43 months, with a decrease in height, weight and volume in these trees (Hardner and Potts, 1994). Further to this, a study on *E. regnans* showed that while vigorous open-pollinated progeny were indicative of high breeding value, self pollinated progeny that are more easily produced than outcrosses, may prove useful for estimation of genetic parameters (Griffin and Cotterill, 1987). This may prove important for propagation and survival of paddock trees from local seed stock.

Landscape scale genetic studies are required for Eucalypt species that are most commonly found as paddock tree species. This is because pollination rates, seedling fitness and the size of seed sets will play a large role in the success of any revegetation attempts.

2.3 Threats to Paddock Trees

Threats to paddock trees in Australia, and the causes behind these have been well documented (Sullivan and Venning, 1982;Reid and Landsberg, 1999). Threats can be summarised as clearance, premature death (dieback) and natural senescence, all coupled with a lack of recruitment. Dieback in Australia has been directly attributed to insect damage, nutrient enrichment, tree pathogens (Reid and Landsberg, 1999), and overstocking with grazing animals causing soil compaction, fertiliser drift and ring-barking of trees (Cutten and Hodder, 2002). Rising saline water tables, associated with native vegetation clearance, also cause increased rural tree mortality (Kile, 1981;Paton et al., 1999). Overall the cause of dieback and therefore tree loss is the result of agricultural practices that are detrimental to tree health, be they pasture improvement, grazing or clearance.

Reduced recruitment among paddock trees is a noted problem (Croft and Venning, 1983;Paton and Eldridge, 1994), and this has been attributed to grazing management practices (Sullivan and Venning, 1982;Cutten and Hodder, 2002). New diseases, such as Mundulla Yellows, first recorded in South Australia, but now reported in others States including Western Australia, New South Wales, Victoria and the NT, have the capacity to potentially devastate remaining paddock trees and attempts to revegetate (Paton and Cutten, 2000). Mundulla yellows is particularly significant in that it slowly kills trees and shrubs of all ages including seedlings and saplings in revegetation programs (Paton and Cutten, 2000). The causal agent and its method of dispersal are yet to be identified (Paton and Cutten, 2000).

Quantifying the impact of threats is further complicated by the fact that all tree loss leads to greater exposure to climatic conditions for remaining trees, thereby putting them at greater risk (Cutten and Hodder, 2002). Several studies in Australia have attempted to quantify the loss of paddock trees from the landscape. In central New South Wales, tree decline was estimated at 20% over a 40 year period, with clearance identified as the major cause of loss (Ozolins et al., 2001). In a study in Victoria in the Byawatha Hills, tree loss was estimated at between 40% to 50% over a 29 year period, with loss attributed to dieback rather than clearance (Leahy, 2003). Based on the New South Wales results, where clearing is the predominant cause of tree loss, the total loss of paddock trees from the intensive agricultural areas of Australia could occur within 40 to 185 years (Gibbons and Boak, in press).

In the south east of South Australia, tree decline for Red and Blue Gum communities was estimated since 1945, using aerial photography. Results over the region varied from 8% to 64% decline over approximately a 33 year period, where the 8% was attributed to natural and premature death, with the 64% representing secondary clearance for agriculture (Sullivan and Venning, 1982). In this same region of South Australia, (Paton and Eldridge, 1994), surveyed an area of 17,500ha and found that 81% of sites contained eucalypts with some form of dieback. They concluded that poor tree health was widespread with dieback most severe amongst isolated trees. While their data suggested insect attack as the primary factor causing poor health, high insect populations were suspected to be a symptom rather than the cause of ill-health (Paton and Eldridge, 1994). In areas where premature death are the main causes, a continued 40% loss over a 29 year period, as in the Victorian study, would see total tree loss in approximately 45 years. These dieback estimates assume that rates of loss will remain constant over time. As noted earlier, tree loss in itself causes further loss. The more likely prediction will be that rates of loss would be expected to increase over time, making these time periods for loss, overestimates.

Intensification of agricultural practices is an increasing threat to paddock trees, as farmers require more space to undertake new types of production. In South Australia for example, a large component of applications for paddock tree clearance are to enable the introduction of irrigation crops and vineyards, many on paddocks previously used for grazing. In the period January 1997 – June 2003 17,448 trees (33% of total trees applied for) were applied for clearance for irrigation crops and vineyards, with 9,742 (39%) approved (DWLBC, 2003). This opened up an estimated 11,563 ha for development (DWLBC, 2003). In other Australian States where clearance legislation is less restrictive, intensification of agriculture could see an even greater reduction in paddock trees as farmers pursue new production opportunities.

The distinction between loss attributed largely to clearance versus premature death is important. The first is the result of a deliberate management decision, and the latter is unintentional. Preventing clearance is necessary to maintain existing paddock trees, however unintentional tree loss through dieback requires immediate attention if Australia is to avoid the loss of the majority of its remaining paddock trees over time.

2.4 Policy Context

Native vegetation clearance has been a constant feature of agricultural development in Australia since European settlement. In South Australia, for example, over 80% of the agricultural zone has been cleared (Cutten and Hodder, 2002), and pressure to clear paddock trees, to make way for agricultural development is high. Legislation across Australia with regard to clearance approval for paddock trees is varied.

2.4.1 South Australian Native Vegetation clearance controls

South Australia was the first Australian State to introduce comprehensive controls on the clearance of native vegetation in 1983. The controls have been progressively strengthened since that time, firstly through the *Native Vegetation Management Act 1985*, and subsequently through the *Native Vegetation Act 1991*. A major amendment to this Act is currently before State Parliament, which, among other things, will formally end broadacre clearance in the State.

The clearance of all naturally occurring native vegetation is protected under *the Native Vegetation Act*, including trees, shrubs and groundcovers, and native vegetation under water (e.g. sea grass). Unless clearance is exempt subject to the Regulations under the Act, the Native Vegetation Council (NVC) must approve clearance. The Council may not approve clearance of native vegetation where such clearance is significantly at variance with principles of clearance contained in Schedule 1 of the Act, which relate to biodiversity, amenity and land degradation values. The Act currently provides that a tree considered by the NVC to be isolated, may, in certain circumstances, be approved for clearance at variance to the Schedule 1 principles. However, a condition of such clearance must secure a net environmental gain by the establishment of native vegetation elsewhere on the property.

As previously mentioned, a trend away from grazing to more intensive agriculture (particularly vineyards and extensive irrigation systems) and plantation forestry has resulted in a large number of applications to clear paddock trees. Applications to clear paddock trees in South Australia are currently assessed against the principles of clearance (*Schedule 1 of the Native Vegetation Act 1991*) on a property-by-property basis. A Point Scoring System (PSS) has been developed to assist in the assessment of the wildlife habitat value of a tree – Principle 1(b) (Cutten and Hodder, 2002). Field data is collected on the tree species, height, diameter, health, and the number and size of hollow entrances. Points are attributed to each of these categories. Trees also gain points if they provide habitat for threatened species.

Table 1 ***Summary of the Point Scoring System (Cutten and Hodder 2002)***

Attribute	Method	Low value (1 point)	Medium value (2 points)	High value (3 points)
1 Height	Height measured in metres	Score is relative to expected height categories developed for each tree species		
2 Health	Dieback measured to nearest five percent	Score categories increase as dieback decreases		
3 Hollow entrances	Number and size of hollows measured	No hollows	1-4 small or 1 medium visible	5+ small; 2+ medium; 1+ large; or 1-4 small and 1 med visible
4 Suitability for use by threatened bird species	Subjective assessment made by bird expert based on field and regional data, and tree photo	Common species only	1 Uncommon species (at regional, state, or national level)	At least 2 Uncommon, or 1 or more Rare species (at regional state, or national level)
5 Density	Distances measured from the tree canopy to the nearest other tree canopy edge	Wide separation *Tree more than 50 m away from all other trees, or two trees less than 50m apart, but each more than 50m away from all other trees*	Medium separation *3 or more trees each within 5 to 50m of at least one other tree in the group; or two trees less than 5m apart, with at least one being within 5 to 50m of at least one other tree*	Little separation *3 or more trees each within 5 metres of at least 1 other tree in the group*
6 Proximity to native vegetation	Distance from tree to block of native vegetation at least one hectare in area	200m or more from block of native vegetation	50m to 200m from block of native vegetation	Within 50m of block of native vegetation

The suitability of a tree as habitat for a threatened species is based on various attributes, including the proximity of a major source habitat and whether the tree is part of a landscape link between source areas. Much of this latter information is based on expert knowledge rather than empirical data. The points allocated to each category are weighted and summed for a total wildlife habitat score. A summary of the categories and their methods of determination may be found in Table 1.

The final wildlife habitat score is combined with comment on the other clearance principles to make a recommendation to the Native Vegetation Council whether clearance should be approved, approved with conditions, or refused. Conditions generally include requiring an environmental gain somewhere else on the property by the retention of existing native vegetation or the regeneration of a degraded area of native vegetation and fencing to restrict stock access, or revegetation (with local provenance stock) of a cleared area. Proposed changes to the Act, currently being debated in Parliament, require an environmental gain to be achieved as a condition of a clearance approval. Where this is not possible on the property where clearance is proposed to take place, the applicant may seek to contribute to the Native Vegetation Fund in order to achieve the purpose directly.

The assessment method provides for consistency across applications, but does not facilitate an assessment of a tree's biodiversity value at a landscape scale. A pilot project was consequently undertaken in order to examine the possibility of mapping trees and therefore providing a regional context for clearance (Bickerton, 2001).

2.4.2 Interstate Legislation

In the ACT all native vegetation, including paddock trees requires a permit for removal (ACT Parliamentary Council, 2002). In New South Wales under the Native Vegetation Conservation Act 1997, clearance of paddock trees is permitted for up to 7 trees per hectare per year for on farm use (Land and Water Conservation, 1999a), or clearance of 7 trees per hectare for pine plantation or irrigation establishment in extensively cleared regions such as the Murray and Murrumbidgee regions (Land and Water Conservation, 1998;Land and Water Conservation, 1999a;Land and Water Conservation, 1999b). Western Australia's current proposed legislation, the Environment Protection Amendment Bill 2002, proposes that all native vegetation will require a permit for clearance, and this will include paddock trees (Government of Western Australia, 2002). Landholders in Victoria wishing to clear native vegetation, including paddock trees over areas larger than 0.4ha, must apply for a permit administered and enforced by Local Government through their planning schemes (Natural Resources and Environment, 2002b). However areas of land less than 0.4ha, containing native vegetation, do not require clearance approval (Johnson, 2002). In the States of NSW, and Victoria, the exemptions for paddock tree clearance leaves many trees unprotected by legislation and may facilitate their adhoc clearance over time.

Dead trees are protected by clearance legislation in the ACT (ACT Parliamentary Council, 2002) and some dead eucalypt trees with hollows are protected in the West Wimmera Shire Council in Victoria (Department of Infrastructure, 2001). In SA large dead trees that are habitat for threatened species listed under the *Commonwealth Environment Protection and Biodiversity Act 1999* are protected under the Native Vegetation Act 1991 (Government of South Australia, 2003). Dead trees are known nesting trees for rated species, such as Red-tailed and Yellow-tailed Black Cockatoos in South Australia and Victoria (Croft et al., 1999).

2.4.3 Clearance versus Offsets and Net Gain

Clearance legislation in the Australian states of Victoria, South Australia, New South Wales, and in proposed legislation in Western Australia includes the principles of 'no net loss' or 'net gain' (Natural Resources and Environment, 2002a;Land and Water Conservation, 1998;Cutten and Hodder, 2002;Government of Western Australia, 2002). This implies that when clearance is consented, that areas of vegetation be set aside or restored for conservation. Net gain is defined as:

" *A reversal, across the entire landscape, of the long-term decline in the extent and quality of native vegetation, leading to a Net Gain*." (Natural Resources and Environment, 2002a p3).

As an example of this, in South Australia when clearance consent is granted, 'set-aside' conditions are imposed on the landholder (Cutten and Hodder, 2002). In the period January 1997 – June 2003 25,083 trees were consented for clearance with 9,702 ha of set-aside required in return, 2,639 ha of which was existing native vegetation, with the remaining 7,073 ha to be set-aside for recruitment With reference to this Cutten and Hodder (2002) point out that any offsetting vegetation (revegetation) runs the risk of failure and that set-asides are usually on poorer quality soils. Additionally they point out that trees possessing hollows may be 200 to 300 years old and that there is therefore a long period of loss before there is any balance or gain from new trees. In the Victorian strategy there is a strong focus on protection for higher conservation significant vegetation where the aim is an overall net gain from a combination of clearance and revegetation (Natural Resources and Environment, 2002b). In the proposed Western Australian legislation one of the conditions may be that the clearing permit may require the reserving of vegetation on the property to offset clearing (Government of Western Australia, 2002). In reference to 'trading options' (such as the South Australian, Western Australian and Victorian examples) for clearance Cutten and Hodder (p 31 2002) state that :

" *Trading' trees in the true sense of the word – clearing one tree in return for retaining another tree, provides no environmental benefit, only loss of trees from the system*".

2.5 Restoration

In the South Australian system the order of priority favored for paddock trees is: re-establishing vegetation around intact habitat; re-establishing vegetation in degraded habitat; re-establishing vegetation around paddock trees and; revegetation on cleared ground (Cutten and Hodder, 2002). The South Australian experience has noted problems with prescribed revegetation, that include low compliance, along with a current lack of monitoring to test its effectiveness as replacement habitat (Cutten and Hodder, 2002). Reid and Landsberg (1999) note that revegetation activity in Australia has been minor. A common guiding principle often used is that other things being equal, regeneration generally provides habitat of higher biological value than replanting (Cutten and Hodder, 2002).

In reality, very little research has been done into the efficacy of revegetation for biodiversity conservation. In particular, using the South Australian example, there has been no biological monitoring of set-aside areas. Consequently, information about their progress and evidence of their suitability as habitat has never been obtained. Other studies however, point to the inadequacy of such revegetation attempts. In the Victorian Byawatha Hills study, the onground experience found that fencing remnants with the intention of regenerating naturally from local seed had limited success (Leahy, 2003). This study found that the barriers to natural regeneration, even when stock were excluded, included seed supply, soil condition (including compaction and altered chemistry) competition, predation and competition with grasses (Leahy, 2003). In a study of revegetation areas in part of the Mount Lofty Ranges in South Australian, Harris (1999) concluded that the majority of revegetation areas were small (< 10ha), were linear in shape and distant from other remnant vegetation, and contained trees at artificially high densities. In addition to this no native ground covers had established. This study also found that in remnant vegetation, trees often had canopy diameters as wide as they were tall, whereas in the revegetation areas, the eucalypts had no lateral branches (Paton et al., 2003). Significantly, trees develop their lateral branches as they grow taller. Branching always occurs at the tallest or growing point of the sapling or tree, and hence, later thinning of trees will not produce the desired lateral branches found in remnant trees (Paton et al., 2003). According to Ryan (1999), current revegetation for land and water degradation results in poor quality habitat. A review on studies of bird use in revegetation sites in Australia suggests that the majority of bird species using them are common generalist or edge species (Ryan, 1999;Paton et al., 2003).

Paddock tree recruitment will need to be addressed at the landscape scale if paddock trees are to persist into the future. Conditions that allow recruitment of paddock trees need to be created in order for the resource to be renewed (Gibbons and Boak, in press). In addition to this, active management of the recruiting trees may need to be undertaken to ensure that these replacement trees establish, survive and develop at appropriate densities to allow lateral branching.

2.6 Knowledge Gaps

Some of the key knowledge gaps with regard to the biodiversity conservation value of paddock trees include:

- the relationship of paddock tree density and age structure on use by wildlife, particularly birds with regards to species diversity and abundance;
- timing and quality of floral resources (nectar), seeds and foliage production;
- the effect of time since clearance of trees on the remaining assemblages of species (Collard, 1999)
- the effect of time since clearance of trees on long term health of remaining trees (Celebrezze et al., 1996);
- the effect on remaining fauna populations, as paddock tree health declines (Paton and Eldridge, 1994);

- the effect of isolation of trees and distance from nearest woodland patches on their habitat value;
- the effect on genetic processes of past clearance and current remedial actions;
- the success or otherwise of recruitment and revegetated areas that have been set aside as future habitat (Cutten and Hodder, 2002);
- Research to compare between success of roadside recruitment and fenced paddock tree recruitment (Leahy, 2003).

Other key gaps in the farm production value of paddock trees include:

- a lack of data examining the effects of tree species and spacing on pasture growth (Bird et al., 1992);
- a lack of field studies examining the hydrological role of large isolated trees in agricultural areas of Australia (Celebrezze et al., 1996);
- the direct and indirect economic benefits of retaining tree in the agricultural landscape.

3 MAPPING METHODS AND RESULTS

3.1 Mapping Methods

The extant and pre-European vegetation of the South East and Tintinara study areas had previously been comprehensively mapped at 1:40,000 (Heard and Goodwins, 1999;Croft, 1999;Kinnear and Gillen, 1999;Croft, In prep). This was used for analysis of vegetation characteristics of the study areas to determine remnancy of plant communities.

The existing extant mapping of native vegetation includes most patches larger than one hectare in size. There is no guarantee of native understorey being present in these patches although for a majority there would be some. The pre_European settlement vegetation mapping depicts the likely distribution of plant communities prior to clearance. For both extant and pre-clearance mapping plant communities are described according to their dominant and co-dominant overstorey and understorey species. In some cases other tree species not listed may also be present, and group descriptions are a guide to what is most likely to be found. Pre-European vegetation mapping boundaries may in some cases be spatially inaccurate and are only ever a guide to the original situation they are attempting to depict.

3.1.1 *Digitising*

The locations of trees were mapped from digital 1:40,000 ortho-rectified aerial photographs. Ortho-photos were selected because of their high resolution of individual canopies and positional accuracy of +/- 9m. For the South East and Tintinara study areas, fifty-one photographs consisting of 12 false colour Infrared and 39 colour, and 20 false colour infrared were used respectively. South East photographs were dated 1997 and the Tintinara photographs were dated December 2002. Digitising of the South East study area was undertaken from December 2001 to June 2002, while digitising of the Tintinara study area was undertaken from April 2003 to September 2003.

Individual trees were mapped from the digital photographs in ArcView 3.2 GIS as points, using the best estimate of the centre of the stem of the tree. Trees were mapped at a consistent on-screen scale of approximately 1:3,000. Trees within, or having canopies continuous with existing mapped vegetation blocks (> 1ha) were not mapped. Trees were coded according to their location in order to ensure that native trees could be separated from potentially non-native trees during analysis (Table 2). Where they were visible, dead trees were mapped. Trees with a canopy width under 6 m could not be confidently identified and were omitted. In the Tintinara study area the method for digitising trees was further refined and paddock trees were coded according to one of 3 canopy size ranges: 6m to 8m, >8m to 14m, >14m.

Code	Location	Status
C	Creek	Native
F	Forestry	Non-Native
H	House, Farm, Windbreak	Unknown
P	Paddock	Native
R	Roadside	Unknown
RR	Road Reserve	Native
V	Vegetation block	Native
D	Dead	Unknown

Table 2 Tree point location and status categories and codes

Groups of remnant trees with a cohesive canopy and larger than approximately 10 individuals or approximately 0.5ha in size, were mapped as polygons and coded as Trees Native, where they had not already been mapped. For the Tintinara study area, additional polygon categories of Shrubs/Regrowth, Windbreaks, and Roadsides were added to facilitate quicker data capture of these vegetation categories.

3.1.2 *Methods for determining canopy gaps*

Trees in Australian woodlands have natural canopy gaps. The canopy gap is usually measured in the field to assist with calculating the percentage crown cover and percent foliage cover of a plant community in order to define its structural classification, e.g. Woodland or Open Woodland (Walker and Hopkins, 1990).

We used measured canopy widths, together with guidelines for woodland crown separation ratios to estimate the range of canopy gap distances for each plant species in the South-East study area (after Walker and Hopkins, 1990;Heard and Channon, 1997). A conservative canopy gap estimate of 5 m was subsequently adopted for all plant communities.

3.1.3 Conversion to paddock tree cover

To enable digitised trees to represent actual area cover across the study area, the point data were converted into canopy cover. The decision to use cover rather than individual point data was to ensure the transferability of this method to other mapping methods, particularly remotely sensed ones. The rules for converting the paddock trees to canopy cover were different for the two study areas. This was due to the information regarding error obtained from the ground truthing of tree canopies in the south east study area, prior to the digitising of the Tintinara study area, and the differences in plant species growth forms of the two study areas.

For the South East study area, in order to convert each tree point into canopy cover, an average canopy diameter was determined for trees within each mapped pre-European plant community. One hundred trees (e.g. paddock, road reserve, or creek line trees) were randomly selected from within each pre-European plant community. For each tree, the canopy diameter was measured on-screen from 1:40000 digital ortho-photos. Means and 95% confidence intervals were calculated for canopy diameters of each pre-European community type (Figure 2). Points were buffered in ARC/INFO using the mean canopy radius (i.e. half the diameter) for trees falling within each pre-European mapped community. The error associated with generating cover from an average species canopy diameter for the South East study area are discussed in Section 3.2.5.

After ground truthing of 878 individual paddock trees in the south east study area, the majority of the GIS generated canopy cover error was determined to have come from the variability in tree canopy sizes that occurred over a small area. This is because trees of the same species are not necessarily all the same size, and because often there is a mix of tree species within any one area, tree canopy sizes are not necessarily consistent across the same area. To minimise this error for the Tintinara study area, trees were allocated to a size category during the digitising process. The medium of these was use as a basis for determining the buffer size of the point. For the 6-8m category, a 7m diameter was used as the basis for the radius buffer; for the >8 – 14m category an 11m diameter was used; for the >14m category, a 20m diameter was used.

For both study areas the canopy conversion process was the same. Polygons (buffered points) were converted to a raster layer of 5 m cells. In the raster conversion process, some loss or gain of canopies occurred where the 5 m cell size limited the conversion of polygons to multiples of 5m cells. This process is random, in that the raster cell dedicates the whole cell to tree cover if greater than half of the cell contains tree cover. At most, any single tree could be up to 4 m wider or narrower than the original buffered point; however, this is randomly averaged across the dataset.

Cover for potentially non-native trees (e.g. trees along roads and near houses) was estimated using a similar method on remaining tree location categories. In this case, trees were sampled across the study area because it was assumed that cover from potentially non-native trees would not differ with respect to original vegetation type. No field testing of these canopy measures was undertaken.

Trees used to determine paddock tree cover included paddock trees, road reserve trees, and creekline trees. Also included in the total cover calculations were the additional small clumps of paddock trees digitised as polygons rather than points. Trees digitised in the categories of house, roadside, and dead trees were removed for cover calculations. House and roadside trees could not be guaranteed to be native tree cover. Where roadside trees did provide native vegetation cover, it was decided that the presence of understorey and the contiguous nature of roadsides meant that they should not be included in initial cover estimates for paddock trees. Dead trees were not considered, as they provide no vegetation cover *per se*.

In order to ensure transferability of methods, roads were buffered by 20 m on either side in order to remove roadside vegetation. Areas with mapped native vegetation cover were not included in the paddock tree cover estimates, nor were areas with mapped planted vegetation cover (e.g. pines, vineyards, etc). A summary of digitising and conversion to cover is found in Figure 3.

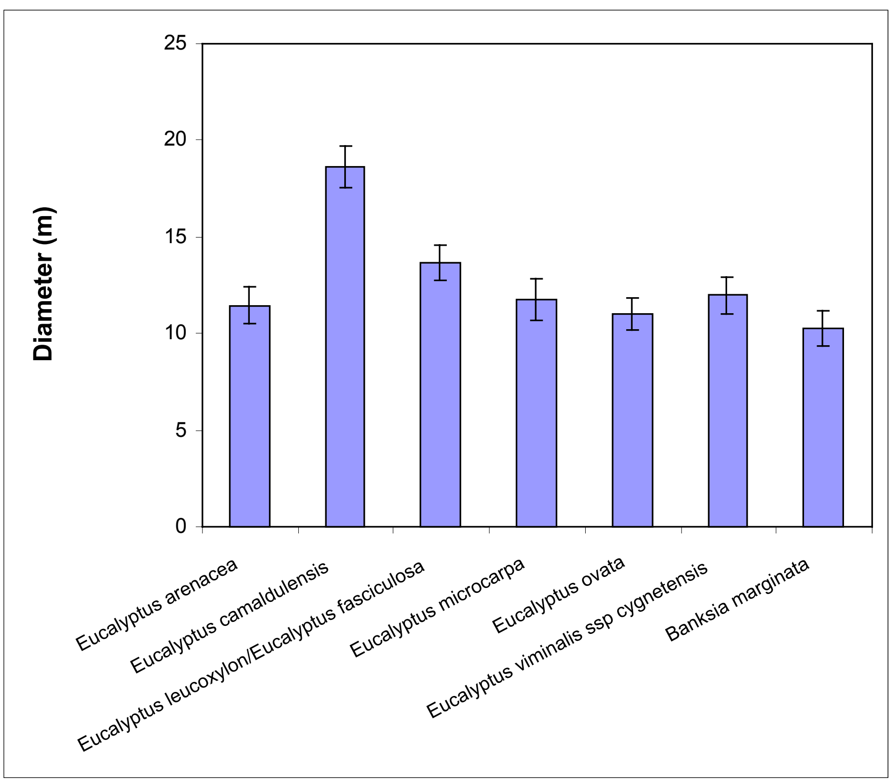
Total canopy cover provided for pre-cleared and extant vegetation, excluding the paddock trees was calculated for each woodland pre-European plant community, in order to provide a baseline for remnancy.

3.1.4 Patch Sizes

For the purposes of describing the cover in terms of its fragmented nature and not just as the amount of total canopy cover, individual patches of tree or trees were identified. A "patch" was defined as any area with a cohesive canopy area of greater than or equal to 25 m^2 (5 m by 5 m, or one cell) and greater than 5 m from adjacent woody vegetation. This was based on the estimated minimum natural canopy gap for these woodlands. Canopy edges that had only one empty cell between them and the next canopy edge were defined as being within the same patch. The minimum possible size of the smallest tree and therefore the minimum patch size was greater than or equal to 25 m^2 (5 m by 5 m, or one cell).

Patch size was then calculated based on the total area occupied by the canopy or canopies and the 5 m gaps between and around them. The patch size distribution of the paddock trees was calculated for the entire dataset, and then separately for each pre-European plant community by overlaying the paddock tree layer with the pre-European vegetation mapping (Croft, 1999;Croft, In prep). Patch sizes were determine as < 0.04ha (1-2 trees), < 0.06ha (2-3 trees), <0.1ha (5-20 trees), <0.5 ha and <1ha. These patch sizes were chosen to match those of other paddock tree mapping methodologies (Gibbons and Boak, in press) so that results would be comparable. Canopy Cover within these patch sizes was calculated based on the actual area occupied by canopies in grid cells, i.e. the gap area between tree canopy edges was not included in the canopy cover calculations. The aim of examining different patch sizes was to determine the extent of how much of the paddock tree cover existed as individual trees versus increasingly larger clusters or clumps of trees.

Figure 2 ***Canopy diameters of dominant tree in woodland pre_European communities in the study area. Error bars are 95% confidence intervals***



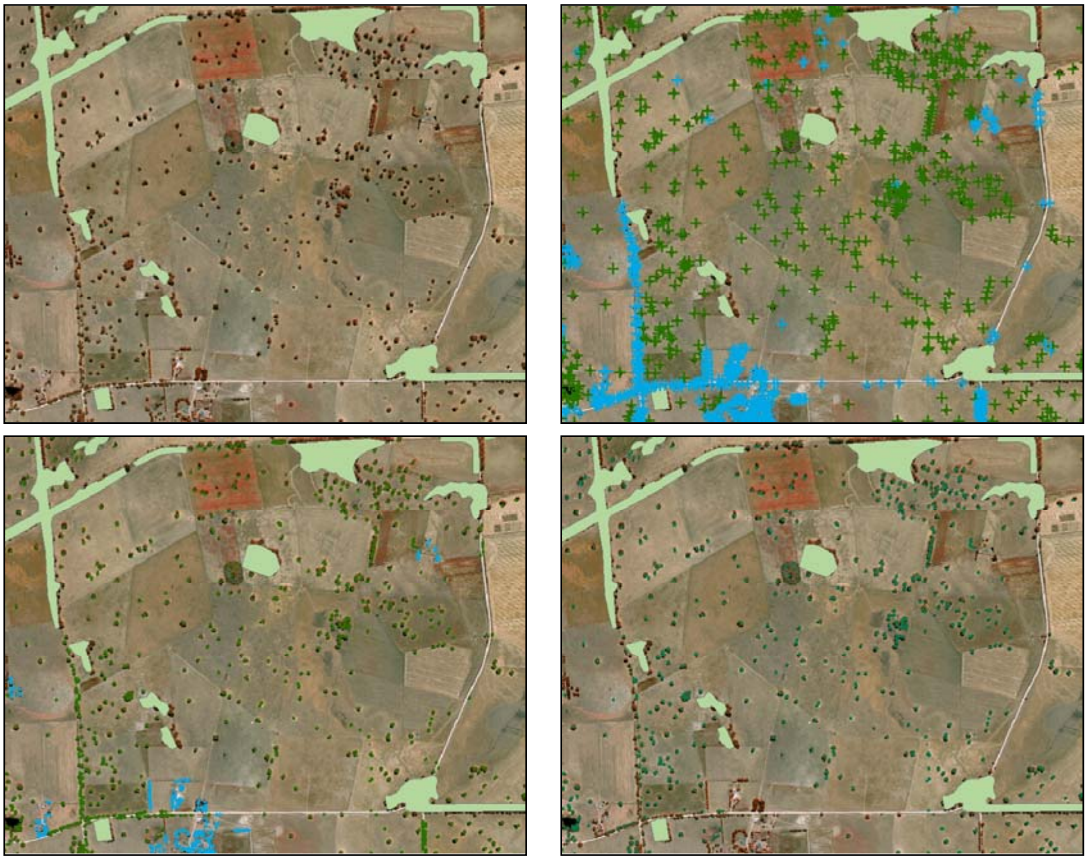


Figure 3 Illustration of the conversion of digitising to canopy cover. *At top right is a portion of the study area with existing native vegetation cover mapping displayed as green polygons. At top right, all trees have been digitised with a point. Paddock trees are green, and house and roadside trees are blue. At middle left, points have been converted to areas using the canopy estimates for each pre-European vegetation community. At middle right, a vector to raster data transformation has occurred, with tree cover represented as grid cells. The completed dataset is displayed without a photo at bottom left.*

3.1.5 *Mapping Error*

Digitising

Exact locations of the stem centres of trees at photo edges were difficult to determine because of the positional error associated with photo edges and the effect of shadow. To minimise this error in the South East dataset, the location of each tree at a photo edge was checked against an adjacent photo and the point was placed where the tree images overlapped. For the Tintinara dataset, photo edges were buffered 600m inwards, and as photos overlapped by approximately 1km, digitising was not undertaken on these edge areas.

Distinguishing trees from shadows was more consistent on the colour infra-red photos. Scattered paddock trees over a dark understorey (e.g. bracken) were more difficult to distinguish than trees over a contrasting pasture or cultivated field. Trees within or near wetlands and dams were more difficult to distinguish. Dead trees were difficult to identify owing to the absence of a canopy, and were only mapped where their identity was certain. Standing dead trees may have been substantially underestimated.

The accuracy in identifying and mapping individual trees differed between plant communities, depending on the growth form of the dominant species. For example, correctly identifying all individual paddock trees of *Eucalyptus camaldulensis* (large single stems with spreading canopies in an open woodland) was possibly more consistent than identifying individuals within *Eucalyptus viminalis* and *Eucalyptus arenacea* communities, which assume a multi-stemmed (mallee) form in tight clumps and can be difficult to identify as individuals except by site inspection.

Conversion to Canopy Cover

Extensive field data collection of tree data from 49 4ha study sites was undertaken for this project. Tree canopy diameter measurements were collected for 897 individual paddock trees and 19 tree clumps in the study area. These measurements were then used to generate an actual canopy cover for each tree, and hence site canopy cover, in the 4ha study sites chosen, to compare against the canopy cover layer generated using the average canopy diameters as described above. These two measures of cover of the 4ha cells were then compared to determine how well correlated the generated mapping was with the actual cover it represents.

3.1.6 *Linking to a database*

Since 1997, BAS assessment officers have collected field data utilising the Point Scoring System for each paddock tree in a clearance application. Many of these had already been digitally compiled for the South Australian agricultural regions within a database. Currently containing nearly 20,000 individual tree records. Of these, approximately 14,500 trees are within the South East study area.

For each application within the South East study area, trees under application were linked to the assessment database via a unique number. A total of 2624 trees could be directly linked to assessment data within the database. For trees that were unable to be linked to assessment data, the clearance decision was recorded within the GIS, in order to be able to spatially remove trees that had been consented for clearance. All trees that had been consented for clearance were removed to create a dataset of extant trees as of 2002. This was the final dataset that was used to determine cover in analyses. Comparing trees within the 1997 and 2001 spatial datasets, percentages of tree loss for all pre-European plant communities were calculated.

3.2 Mapping Results

3.2.1 *Remnancy*

The pre-European and extant cover (this excludes paddock trees and patches smaller than one hectare) of plant communities, excluding the paddock tree component within each study area is shown in Tables 3 and 4. The extant mapping assumes a native understorey component that is often but not always present. Both these floristic maps have been used to describe the vegetation characteristics of the study areas. For the South East region, several woodland communities have a conservation status (endangered, vulnerable, rare) based on their remnancy estimates (Croft et al., 1999). These ratings have not been determined for the Murray Mallee Region, within which the Tintinara study area is located.

The most important plant communities, with regards to their original extent, in the South East study are Red Gum Woodland (originally covering 38% of the study area), Stringybark Woodland (18%), Manna Gum Woodland (15%) and Blue Gum and Pink Gum Woodlands with a combined 9%. (Table 3).

The most important plant communities, with regards to their original extent, in the Tintinara study are: Pink Gum Low Woodland (originally covering 22% of the study area), Blue Gum Low Woodland (10%), *E. diversifolia* Mallee (17%), and *E incrassata, E. diversifolia* Mallee (17%), along with the *Banksia ornata* Tall Open Shrubland (14%) (Table 4).

Table 3 Pre European plant community past and extant cover, South East study area

No.	Pre-European Settlement Plant Community	Original Area (Ha)	Original % of Study Area	Extant Area (Ha)	% Remaining of Original Amount (Remnancy)	Status in SE region (Croft et al., 1999)
	OPEN FOREST					
1	**Stingybark** (*E. arenacea*)	49,179.9	18.2	10,542.2	21.4	n/a
2	**Stingybark** (E. arenacea), **Manna Gum** (*E viminalis ssp.cygnetensis*)	2,454.3	0.9	221.4	9.0	n/a
	WOODLAND					
4	**Red Gum** (*E. camaldulensis var, camaldulensis*)	103,262.4	38.2	5,727.1	5.5	Vulnerable
5	**Pink Gum** (*E. fasciculosa*)	8,058.7	3.0	987.1	12.2	Vulnerable
7	**Blue Gum** (*E. leucoxylon ssp. leucoxylon)*	7,071.4	2.6	823.9	11.7	Vulnerable
8	**Blue Gum** (*E. leucoxylon ssp. pruinosa*)	9,046.7	3.3	1,126.4	12.5	Vulnerable
10	**Grey Box** (*E. microcarpa*)	4,220.3	1.6	168.1	4.0	Endangered
11	**Swamp Gum** (*E. ovata*)	2,293.5	0.8	207.8	9.1	n/a
13	**Manna Gum** (*E viminalis ssp.cygnetensis*)	41,598.0	15.4	2,223.8	10.7	Endangered
	LOW WOODLAND					
16	**Buloke** (*Allocasuarina leuhmannii*)	3,369.6	1.2	48.8	1.4	Endangered
18	*Banksia Marginata*	10,835.4	4.0	36.1	0.3	Endangered
19	**Stringybar**k (*E. arenacea*), **Pink Gum** (*E fasciculosa*)	87.3	0	71.0	*81.4*	n/a
	SHRUBLAND					
32	**Dryland Tea-tree** (*Leptospermum continentale*)	1,500.6	0.6	292.1	19.5	Rare
33	*Melaleuca brevifolia*	12,803.4	4.7	222.8	*1.7*	n/a
34	*Melaleuca gibbosa, Hakea rugosa*	257.4	0.1	1.5	*0.6*	Endangered
	SEDGELAND					
38	*Baunea juncea, Chorizandra enodis*	197.6	0.1	68.5	*34.6*	Endangered
39	*Gahnia filum*	13,025.1	4.8	185.4	*1.4*	Vulnerable
40	*Gahnia trifida*	176.5	0.1	0.0	*0.0*	Vulnerable
	HERBLAND					
45	Floating water plants	696.2	0.3	104.1	15.0	n/a
Total		**270,134.5**		**25,278.2**	**9.4%**	

Table 4 Pre-European plant community past and extant cover, Tintinara study area

Gp	Pre-European Settlement Plant Community	Original Area (Ha)	Original % of Study area	Extant Area (Ha)	%Remaining of Original Amount
	WOODLANDS				
1	**Sheoak** *(Allocasuarina verticillata),* **Blue Gum** *(Eucalyptus leucoxylon* ssp.) Low woodland	73	0.1	73	100.0
3	**Stingybark** *(Eucalyptus arenacea)* Low woodland	1,996	2.0	0	0.0
4	**Punk Gum** *(Eucalyptus fasciculosa),* **Blue Gum** *(E. leucoxylon)* Low woodland	841	0.8	0	0.0
5	**Pink Gum** *(Eucalyptus fasciculosa), Xanthorrhoea caespitosa* Low woodland	22,598	22.4	0	0.0
7	**Blue Gum** *(Eucalyptus leucoxylon* ssp.) Low woodland	9,837	9.8	211	2.1
9	**Mallee Box** *(Eucalyptus porosa)* Low open woodland	2,588	2.6	0	0.0
	MALLEE				
10	*Eucalyptus diversifolia* Mallee	18,951	18.8	8,027	42.4
45	*Eucalyptus incrassata, E. diversifolia* Mallee	17,285	17.2	0	0.0
11	*Eucalyptus dumosa, +/- E. leptophylla* Mallee	4,881	4.8	0	0.0
15	*Eucalyptus leptophylla, Melaleuca lanceolata* Open mallee	20	0.0	0	0.0
16	*Eucalyptus rugosa* Open mallee	93	0.1	0	0.0
17	*Eucalyptus calycogona, E. dumosa* Very open mallee	26	0.0	0	0.0
19	*Eucalyptus incrassata* Open low mallee	4,310	4.3	224	5.2
	SHRUBLANDS				
21	*Banksia ornata* Tall open shrubland	13,866	13.8	192	1.4
23	*Melaleuca acuminata, M. lanceolata, +/- Eucalyptus socialis, +/- E. leptophylla* Tall open shrubland	2	0.0	2	100.0
26	*Xanthorrhoea caespitosa/semiplana, +/- Banksia marginata* Tall very open shrubland	111	0.1	111	100.0
30	*Melaleuca brevifolia* Tall open shrubland	3,249	3.2	6	0.2
	SEDGELANDS				
36	*Gahnia filum, Samolus repens* Sedgeland	44	0.0	0	0.0
Total		**100,771**		**8,846**	**8.8%**

3.2.2 Digitising

Within the South East study area the final dataset contains 287,721 digitised trees, with 215,736 of these classified as native trees and of these 206,232 specifically located in paddocks. Of these paddock trees 5,275 (2.6%) were dead. Trees cleared between 1997 and 2001 were removed from the final tree layer dataset for cover calculations. Of these, 1,307 trees could be linked directly to the clearance assessment database and 2,566 were unable to be linked but were identified spatially from the plans as having been consented for clearance. In addition 374 ha of paddock tree cover was digitised as polygons.

Within the Tintinara study area the final dataset contains 164,322 digitised trees, with 147,655 of these classified as native trees and of these 147,621 specifically located in paddocks. Of these paddock trees 1,987 (1.3%) were dead. Photos were taken 2 months prior to digitising commencing and hence there was no need to removed trees from past clearance applications. Tree size categories saw this number divided up into 94,322 (64%) small, 40,379 (27%) medium and 11,023 (7%) large trees. In addition 1,804 ha of paddock tree cover was digitised as polygons, some of these were adjacent to existing large vegetation blocks, and these possibly contained some native understorey component.

3.2.3 Canopy gap measures

Dominant canopy species in Australian woodlands by definition only cover between 30% and 70% (Walker and Hopkins, 1990;Specht, 1972). The minimum and maximum canopy gap values were calculated for relevant plant communities within the South East study area (using Walker and Hopkins, 1990;Heard and Channon, 1997) (Table 5). The range of expected gaps varies across plant communities as is listed in Table 5. The canopy gap was used to identify areas where the spatial distribution of dominant trees resembles their pre-clearance densities as shown in Figure 4.

3.2.4 Canopy Cover

The total cover provided by paddock trees (paddock, road reserve and creekline trees) across the South East study area was 4,260 ha. This represents 14.4% of the total native vegetation cover in the area. A map of the South East study area showing all native vegetation cover, including paddock trees, is included with this report.

The total cover provided by the paddock trees (paddock, road reserve and creekline trees) across the Tintinara study area was 2,898 ha. This represents 24.7% of the total native vegetation cover in the area.

A conservative canopy gap of 5m was applied to all paddock trees across both study areas to identify those trees occurring within the same patch (Figure 4). Patches of different areas are highlighted (Figure 4).

A breakdown of the patch sizes for the South East as shown in Table 6, indicates that the majority of paddock tree patches (85%) exist in patches smaller than 0.06ha (approx. 25m x 25m) in size, and approximately 53% of paddock tree cover also occurred in these small patches. A breakdown of the patch sizes for Tintinara as shown in Table 7, indicates that the majority of paddock tree patches (91%) exist in patches smaller than 0.06ha in size and approximately 21% of paddock tree cover occurred in these small patches. In other words, for both study areas, the majority of paddock trees exist as single trees or small groups of trees in the landscape separated by gaps greater than would have existed prior to European settlement.

Table 5 Measured canopy diameters and canopy gap range for selected plant communities in the South East study area

No.	Pre-European Plant Community	Canopy Diameter (m)	Minimum Gap (m)	Maximum Gap (m)
1	**Stingybark** (*E. arenacea*) Open Forest	11.5	3	11
4	**Red Gum** (*E. camaldulensis var, camaldulensis*) Woodland	18.5	5	18
5	**Pink Gum** (*E. fasciculosa*)	13.7	3	14
7	**Blue Gum** (*E. leucoxylon ssp. leucoxylon*	13.7	3	14
10	**Grey Box** (*E. microcarpa*)	11.8	3	12
11	**Swamp Gum** (*E. ovata*)	11	3	11
13	**Manna Gum** (*E viminalis ssp.cygnetensis*)	12	3	12

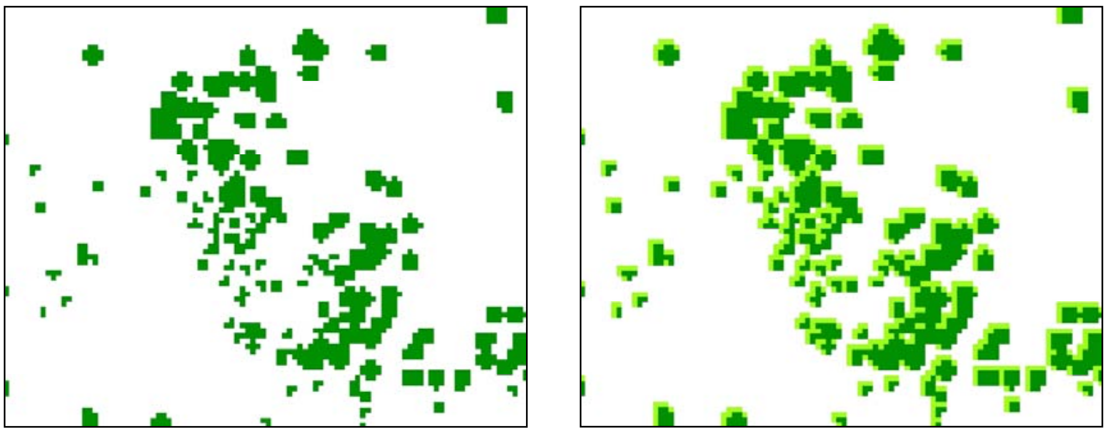


Figure 4 Identification of patches using canopy gaps of 5 m.

On the left, a stand of paddock trees is shown as mapped and converted to canopy cover. On the right, gaps of 5 m have been added in bright green, with the central patch representing approximately 1 ha, the patch to the right of it approximately 0.5 ha, and the patch furthest to the right 0.25 ha.

Table 6 Patch sizes of paddock trees for the South East study area

Patch Size Category	#Patches	%Total Patches	Ha	%Total
le 0.04 ha	64628	**45**	689	16
gt 0.04 and le 0.06 ha	57783	**40**	1573	37
gt 0.06 and le 0.1 ha	12002	8	580	14
ft 0.1ha and le 0.5 ha	9584	7	1036	24
gt 0.5ha < 1ha	524	<1	275	6
gt 1ha	107	<1	107	3
Total	144628		4260	

Table 7 Patch sizes of paddock trees for the Tintinara

Patch Size Category	#Patches	%Total Patches	Ha	%Total
le 0.04 ha	72460	**82**	409	14.1
gt 0.04 and le 0.06 ha	7881	9	203	7.0
gt 0.06 and le 0.1 ha	3723	4	142	4.9
gt 0.1ha and le 0.5 ha	2880	3	314	10.8
gt 0.5ha < 1ha	353	<1	193	6.7
gt 1ha	554	1	1637	56.5
Total	87851		2898	

The percentage of native vegetation cover contributed by paddock trees in both study areas differs between pre-European plant communities (Tables 8 and 9). For both areas, only those plant communities containing a tree layer component i.e. woodland or mallee are discussed.

In the South East study area of the four woodland communities listed in Table 8, Red Gum Woodland has 36% of its extant cover found as paddock trees, Blue Gum Woodland has 13.5%, Pink Gum Woodland has 8.5%, Manna Gum Woodland has 12%. In contrast Stringybark Open Forest has only 2.2%.

All of these are important plant communities with regards to their original cover over the study area i.e. Red Gum Woodland (originally covering 38% of the study area), Manna Gum Woodland (15%) Blue Gum and Pink Gum Woodlands with a combined 9%, and Stringybark Open Forest (18%) (Table 8).

A breakdown of the patch sizes for each plant community in the South East study area is shown in Table 8. For some communities such as Red Gum, Blue Gum and Pink Gum, the majority of paddock trees exist as individual trees or small clumps of trees in patches less than 0.06ha or 0.04ha.

In the Tintinara study area Pink Gum, Blue Gum Low Woodland, and Pink Gum Low Woodlands have been completely cleared and paddock trees are the only remaining vegetation component, with Blue Gum Low Woodland, having 44% of its extant cover found as paddock trees (Table 9). Of the mallee communities (including Stringybark and *E. dumosa* Low Woodlands because of their multi-stemmed trunk form) Stringybark Low Woodland, Mallee Box Low Open Woodland, *E. incrassata*, White mallee Mallee and *E. dumosa, +/- E. leptophylla* Mallee have been completely cleared and paddock trees are the only remaining vegetation component.

Table 8 Cover provided by paddock trees per pre-European plant community type for the South East mapping

Pre European Plant Community	Scattered Tree Cover Patch size	Scattered Tree Canopy Cover (ha)	%Total Mapped Cover (per group)	%Total Mapped Cover (per group)	Remnancy % (per group) excluding Scattered Trees	Remnancy % (per group) including Scattered Trees
Manna Gum (*Eucalytus viminalis ssp cygnetensis*) Woodland (13)	**< 0.04ha**	**184**	**3.7**	11.9	10.7	11.9
	>0.04ha < 0.06ha	44	0.9			
	>0.06ha < 0.1ha	39	0.8			
	> 0.1 < 0.5 ha	75	1.5			
	0.5ha to 1 ha	54	1.1			
	> 1ha	190	3.9			
Stringybark (*E.arenacea*) Open Forest (1)	**< 0.04ha**	**120**	**1.1**	2.2	21.4	21.8
	>0.04ha < 0.06ha	26	0.2			
	>0.06ha < 0.1ha	22	0.2			
	> 0.1 < 0.5 ha	39	0.4			
	0.5ha to 1 ha	25	0.2			
	> 1ha	6	0.1			
Pink Gum (*E. fasciculosa*) Woodland (5)	**< 0.04ha**	**59**	**5.6**	8.5	12.2	13.2
	>0.04ha < 0.06ha	8	0.8			
	>0.06ha < 0.1ha	5	0.5			
	> 0.1 < 0.5 ha	8	0.8			
	0.5ha to 1 ha	9	0.8			
	> 1ha	1	0.1			
Blue Gum (*E. leucoxylon ssp. leucoxylon* or *E. leucoxylon ssp. pruinosa*) Woodland (7&8)	**< 0.04ha**	**154**	**6.9**	13.5	12.1	13.9
	>0.04ha < 0.06ha	34	1.5			
	>0.06ha < 0.1ha	46	2.1			
	> 0.1 < 0.5 ha	51	2.3			
	0.5ha to 1 ha	13	0.6			
	> 1ha	5	0.2			
Red Gum (*E. camaldulensis var. camaldulensis*) Woodland (4)	< 0.04ha	139	1.6	35.9	5.5	8.4
	>0.04ha < 0.06ha	**1442**	**16.6**			
	>0.06ha < 0.1ha	458	5.3			
	> 0.1 < 0.5 ha	843	9.7			
	0.5ha to 1 ha	167	1.9			
	> 1ha	59	0.7			

Of those listed above the most important plant communities with regards to their original cover over the study area would be: Pink Gum Low Woodland (originally covering 22% of the study area), Blue Gum Low Woodland (10%), and *E. incrassata*, White mallee Mallee (17.2%) (Table 9).

For ten of the twelve plant communities listed in Table 9, paddock tree cover represents a substantial component (i.e. greater than 44%) of that communities remaining cover.

Table 9 Cover provided by paddock trees per pre-European plant community type for the Tintinara mapping

Pre-European Plant Community	Scattered Tree Cover Patch Size	Scattered Tree Canopy Cover (ha)	% total extant mapped cover (per group)	% total extant mapped cover (per group)	Remnancy % (per group) exc Scattered Trees	Remnancy % (per group) inc Scattered Trees
Sheoak, Blue Gum *(Allocasuarina verticillata, Eucalyptus leucoxylon* ssp.) Low woodland (1)			0%	0%	100%	negligable
Pink Gum, Blue Gum *(Eucalyptus fasciculosa, E. leucoxylon)*Low woodland (4)	**< 0.04 ha**	**57.1**	**31.4**	100%	0%	21.7%
	> 0.04ha < 0.06ha	32.1	17.6			
	>0.06ha <0.11ha	10.4	5.7			
	> 0.1ha < 0.5ha	39.2	21.5			
	0.5ha to 1ha	9.8	5.4			
	>1ha	33.6	18.4			
Pink Gum *(Eucalyptus fasciculosa, Xanthorrhoea caespitosa)* Low woodland (5)	**< 0.04 ha**	**149.4**	**28.6**	100%	0%	2.3%
	> 0.04ha < 0.06ha	58.6	11.2			
	>0.06ha <0.11ha	49.1	9.4			
	> 0.1ha < 0.5ha	68.2	13.1			
	0.5ha to 1ha	52.9	10.1			
	>1ha	143.6	27.5			
Blue Gum *(Eucalyptus leucoxylon* ssp.) Low woodland (7)	**< 0.04 ha**	**38.8**	**10.2**	44%	2.1%	3.9%
	> 0.04ha < 0.06ha	26.0	6.9			
	>0.06ha <0.11ha	16.5	4.4			
	> 0.1ha < 0.5ha	38.4	10.1			
	0.5ha to 1ha	12.1	3.2			
	>1ha	36.2	9.6			
Stringybark *(Eucalyptus arenacea)* Low woodland (3)	< 0.04 ha	15.8	9.29	100%	0%	8.5%
	> 0.04ha < 0.06ha	7.6	4.47			
	>0.06ha <0.11ha	7.8	4.59			
	> 0.1ha < 0.5ha	20.0	11.76			
	0.5ha to 1ha	11.9	7.00			
	>1ha	**107.0**	**62.94**			
Mallee Box *(Eucalyptus porosa)* Low open woodland (9)	< 0.04 ha	13.8	17.6	100%	0%	3%
	> 0.04ha < 0.06ha	10.3	13.2			
	>0.06ha <0.11ha	4.8	6.1			
	> 0.1ha < 0.5ha	13.6	17.5			
	0.5ha to 1ha	4.4	5.7			
	>1ha	**31.1**	**39.8**			
White Mallee *(Eucalyptus diversifolia)* Mallee (10)	< 0.04 ha	30.0	0.3	7.7%	42.4%	45.9%
	> 0.04ha < 0.06ha	16.5	0.2			
	>0.06ha <0.11ha	14.4	0.2			
	> 0.1ha < 0.5ha	64.6	0.7			
	0.5ha to 1ha	65.3	0.8			
	>1ha	**478.4**	**5.5**			
Eucalyptus incrassata, E. diversifolia Mallee (45)	< 0.04 ha	42.6	9.4	100%	0%	2.6%
	> 0.04ha < 0.06ha	22.1	4.9			
	>0.06ha <0.11ha	14.3	3.2			
	> 0.1ha < 0.5ha	33.9	7.5			
	0.5ha to 1ha	27.3	6.0			
	>1ha	**313.9**	**69.1**			
Eucalyptus dumosa, +/- E. leptophylla Mallee (11)	< 0.04 ha	4.9	19.6	100%	0%	0.5%
	> 0.04ha < 0.06ha	2.7	10.4			
	>0.06ha <0.11ha	1.5	6.0			
	> 0.1ha < 0.5ha	3.0	12.0			
	0.5ha to 1ha	4.0	16.0			
	>1ha	**9.0**	**36.0**			
Eucalyptus incrassata Open low mallee (19)	< 0.04 ha	19.1	3.8	55.5%	5.2%	11.6%
	> 0.04ha < 0.06ha	10.7	2.1			
	>0.06ha <0.11ha	7.0	1.4			
	> 0.1ha < 0.5ha	24.2	4.8			
	0.5ha to 1ha	22.4	4.5			
	>1ha	**195.5**	**38.9**			

The difference in how woodland versus mallee plant communities have been cleared in the paddock situation becomes obvious for the Tintinara study area when looking at the patch sizes for paddock trees in each plant community. A breakdown of the patch sizes for each plant community is shown in Table 9. For the woodland communities such as Blue Gum and Pink Gum, the majority of paddock trees exist as individual trees or small clumps of trees in patches less than 0.06ha. For the mallee form communities, the majority of paddock trees are found in the >1ha category where small clumps of trees have been left, a factor of the way in which mallee trees are either cleared or left i.e. clearance is often done using a chain attatched to a bulldozer, rather than individuals trees being cut down.

3.2.5 Mapping Error

GIS generated cover for the South East study area, based on average canopy diameters was compared with the actual field cover of tree canopy diameters, for each of the 49 paddock tree field sites. This included canopy measurements of 878 individual trees. From an initial scatter plot between site cover and GIS cover within each vegetation type, there appeared to be a strong positive relationship between the two. However, there was more variability in site cover in sites with higher GIS cover. Mean-dispersion modeling was used which allows the fitting of double generalised linear models where the mean and dispersion are modeled simultaneously (Smith and Verbyla, 1999). For this data a linear and quadratic term for GIS cover were found to be significant in the dispersion model. The results indicate that the relationship between GIS cover and site cover is not dependent on vegetation type and can be explained by a common curve. The fitted curve is presented in Figure 5. For more detail see Lorimer (2003). Broadly interpreted, the curve indicates, that at lower site cover, the GIS cover is in general lower than the actual cover, and as both covers increase, they more closely they approach each other. The site variability displayed on either side of the curve indicates that as site cover and GIS cover increases, the variability increases. This was probably due to the number of trees increasing as cover increases. This means there is greater possibility for accumulated error between the generated cover and the actual cover, where actual cover is dependent upon individual tree canopy sizes at each site.

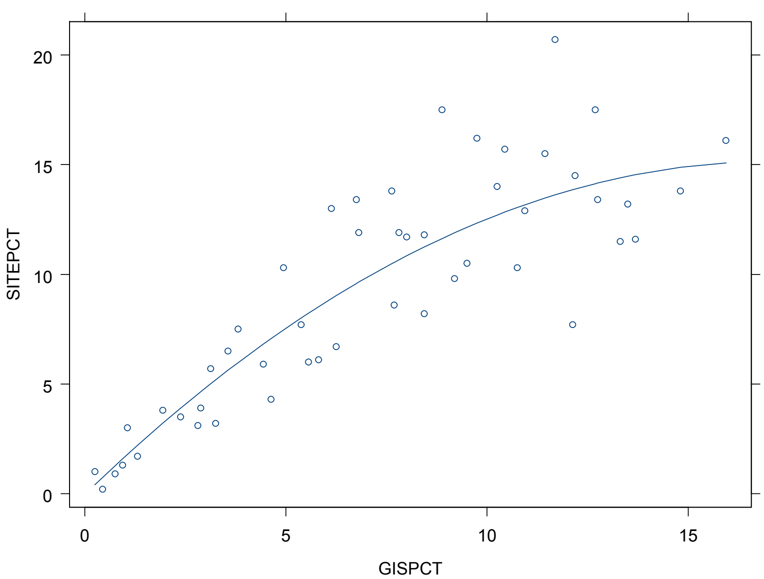


Figure 5 GIS vs actual site canopy cover.

The error for the Tintinara dataset was not possible to calculate as no field data was collected. However, the change in digitising method, which was to place each tree canopy within a fixed size range, was considered to have removed a large amount of the canopy cover error (due to spatial variability of canopies in any one place) that had occurred in the South East data set. This was especially important for the Tintinara region, as the bulk of the trees digitised were in the small category (i.e. 6-8m), and were spatially mixed with larger trees of different species within the same pre-European settlement plant communities.

Using the South East method of averaging canopies within a pre-European community and assigning this average canopy diameter to all trees, would have created more error in the Tintinara dataset than it did in the South East, where trees were generally more homogenous in size within distinct pre-European plant communities. The cell size of 5m however, did restrict the ability to generate accurate tree cover.

For example, for the small, medium, and large trees, the average canopy diameter was 7m, 11m and 20m respectively. Once converted to 5m grids these canopies effectively became $5m^2$, $10m^2$ and $20m^2$ respectively.

3.2.6 Linking to the clearance database – south east study area

Within the study area, 1.8% of trees were approved for clearance between 1997 and 2001 (Table 10).

The largest percentages of loss through clearance were within the pre-European Bulloak (*Allocasuarina luehmannii)* Low Woodland, Pink Gum *(Eucalyptus fasciculosa)* Woodland, and Manna Gum Woodland and Open Forest communities. This indicates that for some paddock tree species, clearance approval is more likely, predominantly because they are often isolated and in poor health because of their already diminished presence in the landscape. Bulloak grassy Woodland is rated as an endangered plant community within the South East region of South Australia, with less than 3% of its original habitat remaining. It is also underrepresented in the State parks and reserve system. Furthermore, many of the remaining mature trees are in poor health owing to heavy parasitism by mistletoe (Croft et al., 1999), and natural regeneration has been inhibited by grazing pressure from rabbits and stock. Pink Gum in association with Blue Gum is rated as regionally vulnerable (7.8% remaining) (Croft et al., 1999). It is believed to suffer particularly from the effects of isolation and insect attack, with a high degree of dieback in Pink Gums recorded in remaining trees in farm paddocks (Croft et al., 1999;Paton and Eldridge, 1994;Croft and Venning, 1983).

Table 10 Trees cleared within pre-European plant communities within the South East study area

No.	Pre-European Settlement Plant Community	Live Native Trees in 1997	Live Native Trees in 2001	Number of trees consented for clearance	% Loss
	OPEN FOREST				
1	**Stingybark** (*E. arenacea*)	23108	22743	365	1.6
2	**Stingybark** (E. arenacea), **Manna Gum** (*E viminalis ssp.cygnetensis*)	74	70	4	**5.7**
	WOODLAND	0			
4	**Red Gum** (*E. camaldulensis var, camaldulensis*)	109019	108262	757	0.7
5	**Pink Gum** (*E. fasciculosa*)	11569	11004	565	**5.1**
7	**Blue Gum** (*E. leucoxylon ssp. leucoxylon)*	7511	7425	86	1.2
8	**Blue Gum** (*E. leucoxylon ssp. pruinosa*)	12645	12636	9	0.1
10	**Grey Box** (*E. microcarpa*)	2723	2621	102	3.9
11	**Swamp Gum** (*E. ovata*)	1172	1134	38	3.4
13	**Manna Gum** (*E viminalis ssp.cygnetensis*)	39190	37472	1718	**4.6**
	LOW WOODLAND	0			
16	**Buloke** (*Allocasuarina leuhmannii*)	2186	2059	127	**6.2**
18	*Banksia Marginata*	479	479	0	0.0
19	**Stringybark** (*E. arenacea*), **Pink Gum** (*E fasciculosa*)	17	17	0	0.0
32	*Leptospermum continentale*	378	369	9	2.4
33	*Melaleuca brevifolia*	2673	2599	74	2.8
34	*Melaleuca gibbosa, Hakea rugosa*	44	44	0	0.0
	SEDGELAND	0			
38	*Baunea juncea, Chorizandra enodis*	48	48	0	0.0
39	*Gahnia filum*	1298	1281	17	1.3
40	*Gahnia trifida*	3	3		0.0
	HERBLAND	0			
45	Floating water plants	156	154	2	1.3
Total		**214334**	**210461**	**3873**	**1.8**

4 BIRD FIELD STUDY METHODS AND RESULTS

Along with quantifying the cover of paddock trees in the landscape, an overall objective of this project is to determine the ecological value of paddock trees at a landscape scale. In addition to their value as remnant vegetation (as a genetic resource, or as a constituent of conservation significant vegetation type), paddock trees provide a functional role as habitat for wildlife. This role is recognised within the South Australian *Native Vegetation Act 1991*.

This section discusses the bird and paddock tree survey that was conducted in the south east study area to capture information on bird use of trees and therefore habitat information. The survey also aimed to capture data about individual tree characteristics for trees that had been mapped and were being surveyed for bird use. The field study focussed on determining whether there was a relationship between the amount of tree canopy cover in an area and bird use. A key requirement of the study is that this information can then be translated back to the mapped tree data for application across the wider landscape.

The following are the key questions that the bird survey aimed to examine.

For the paddock tree vegetation types of Red Gum Woodland and Blue Gum Woodland respectively.

1.Does bird species diversity, species richness and estimated density found in a given area (i.e. per 4ha site), change as tree cover increases?

2. Are the presence and/or abundance of different functional groups of birds affected as tree cover increases?

3. What site variables (e.g. presence of timber, litter) are important in explaining variation in bird species diversity, species richness and estimated density?

4. Which landscape variables are important in explaining bird species diversity, species richness and estimated density, found in a given area (i.e. per 4ha site), for a given % tree cover? i.e.

- Amount of tree/patch vegetation cover within a given radius of the site i.e. 500m 1km 2km 5km
- Distance to nearest native vegetation patch >1ha, > 20ha, >80ha

5. How does bird species richness in nearby native vegetation patches of the same vegetation type (for a 4ha sample area), compare to that in paddock trees?

4.1 Field Study Methods

4.1.1 Paddock tree study sites

In order to determine the relationship between canopy cover over a given area and bird species composition and abundance, plot sizes of 4ha (200m x 200m) were chosen. 4 ha was deemed an appropriate size for capturing bird use, because of the open nature and low density of paddock trees within the study sites and for the practicalities of time and visual limitations for the bird observer of surveying a larger plot size.

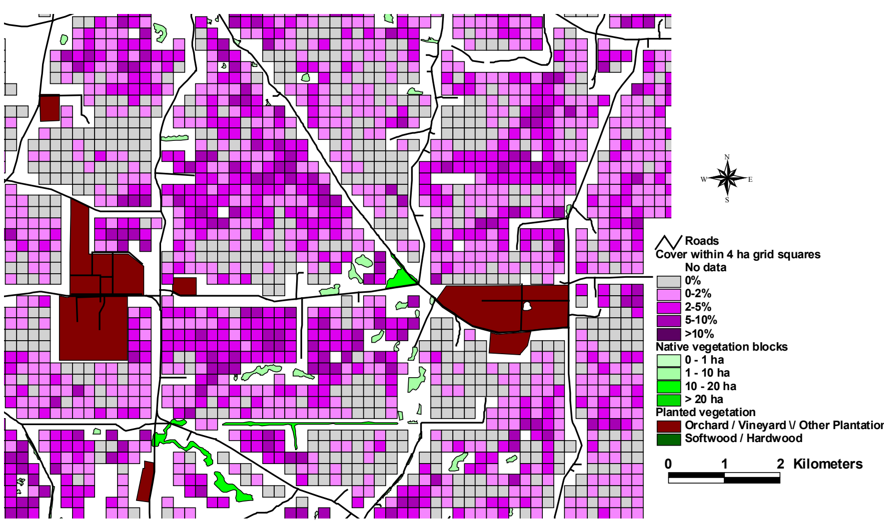


Figure 6 Percentage cover by paddock trees within 4 ha grid squares

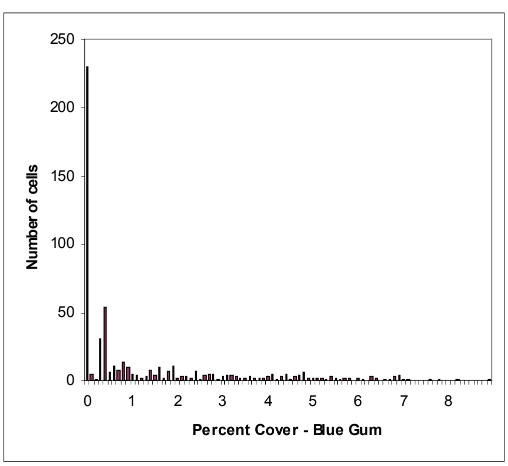
Based on statistical analysis advice, a minimum of approximately 50, 4ha sites was decided upon. As vegetation type is a strong determinant of bird community composition (Major et al., 2001;Recher et al., 1985) two key woodland communities within the study area were chosen. Red Gum (*E. camaldulensis*) and Blue Gum (*E. leucoxylon*), Pink Gum (*E. fasciculosa*) Woodlands were chosen as they represent two of the dominant woodland communities within the southeast study region, together they would have originally covered approximately 47% of the study region. Bird study sites were further limited to within an area of approximately 100,500 ha within the northern half of the study area. This was to minimise the effects of vegetation and landscape change on results, through changes to bird community composition that might naturally occur over the entire study area, which was reasonably large.

Using ARC/INFO, a 4ha (200m x 200m) cell size grid was generated for the study area and % canopy cover was calculated for each cell (Figure 6). The cover provided by paddock trees in both Red Gum and Blue Gum woodland pre-European plant communities per 4 ha grid square was analysed in order to determine the range of cover densities for each plant community in the study area (Figure 7). Sites of 4 ha in size were then selected for use in the field study. The range of cover to be chosen from the 4ha cells was based on a random stratified sampling approach. This was to ensure that a range of cover values would be tested across the study area in order to obtain enough data on each % cover amount.

Additional criteria were then used to determine which 4ha cells were to be used. These were:

- 4ha sites were to be no closer than 100m to, and no further than 500m from, a vegetation block 1ha or greater. The majority of sites chosen were 200m from a vegetation block 1ha or greater.
- 4ha sites to be no closer than 100m to plantations, depressions, creeklines or roadsides.
- No 4ha sites to be closer than 400m to each other
- Sites to be chosen near to patches or roadside patches of remnant Red Gum or Blue Gum woodland
- only sites with non-native understorey (pasture) were chosen

59 potentially suitable 4ha sites were identified. Landholders were contacted in March 2003 through an official letter from the project officer on behalf of the Department. In principal support for the project was sought and gained from the South Australian Farmers Federation (SAFF) and a contact name and phone number for SAFF was provided in the letter. This was followed up by a phone call to the landholder 1 to 2 weeks later from the project officer. Permission to visit 49 sites on 44 private properties was obtained. This consisted of 25 Blue Gum/Pink Gum and 24 Red Gum sites. The final percent cover of each site calculated using the sites based canopy diameters is shown in Figures 8 and 9. Site locations are shown in Figure 10. 43 of the 49 sites were being used for grazing only at the time of the survey, with 6 sites also having some form of crop over part of the site. The Red Gum sites were predominantly grazed by cattle, with Blue Gum sites predominantly grazed by sheep.



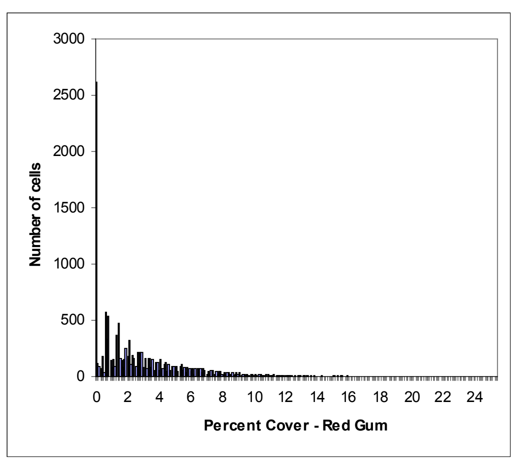


Figure 7 Histograms of cover ranges of paddock trees in Blue Gum (left) and Red Gum (right

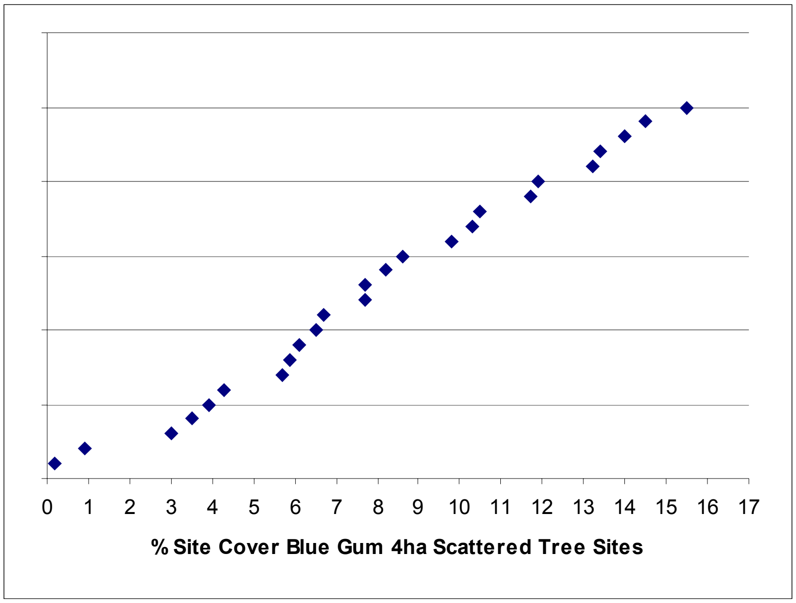


Figure 8 Scattergram of % cover ranges of paddock trees in Blue Gum/Pink Gum Paddock Tree Sites

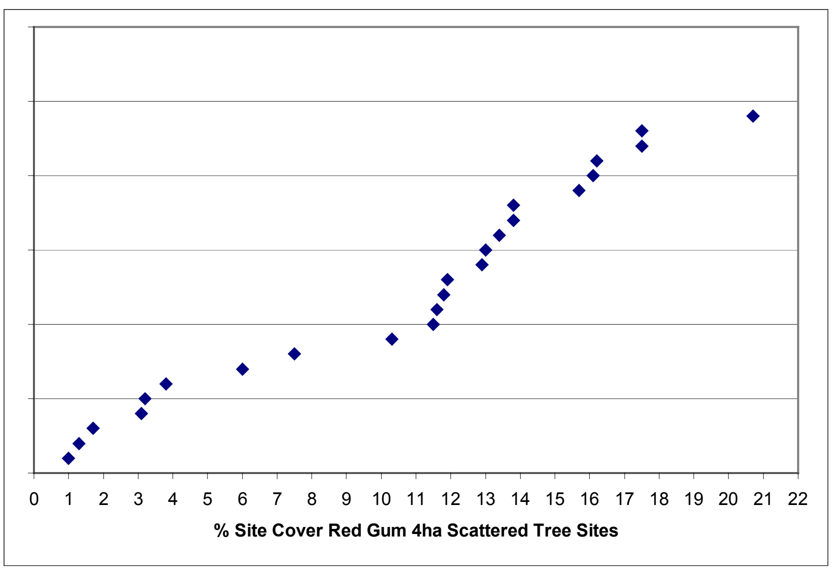


Figure 9 Scattergram of % cover ranges of paddock trees in Red Gum Paddock Tree Sites

4.1.2 Remnant study sites

An aim of the bird study was to determine how the bird species richness and composition in nearby native vegetation remnant (high cover i.e. >50% canopy cover) patches of the same vegetation type compared to that in paddock trees. 4ha study sites were chosen in Red and Blue / Pink Gum remnant patches as close as feasible to the 4ha paddock tree study sites. These remnant sites were 200m x 200m, however in the case of roadsides they were 40m x 1000m. 14 Red Gum and 12 Blue / Pink Gum remnant sites were chosen. Due to a lack of available Blum / Pink Gum Woodland remnants in the field study area, 2 remnant Blue / Pink Gum sites were chosen approximately 5km north of the closest Blue / Pink Gum paddock tree 4ha site.

The sites included:

- Conservation Parks and Heritage Agreements with relatively intact native understorey;
- roadsides with understorey varying from largely to scarcely native;
- remnant patches of overstorey on private properties with some to little native understorey;

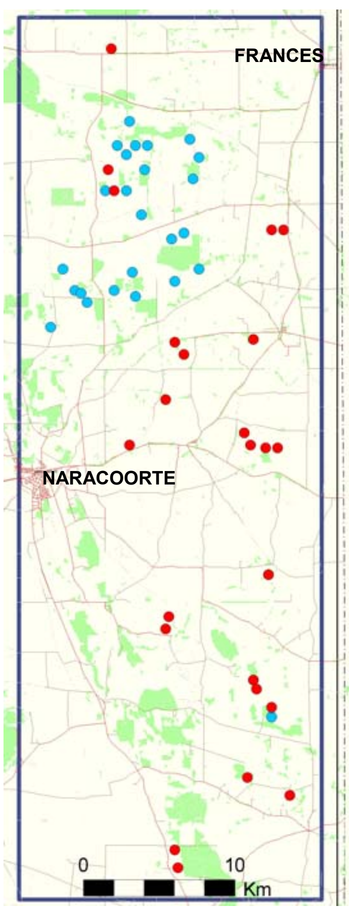


Figure 10 4Ha Paddock Tree Sites

4.1.3 Field Survey: Paddock Tree Data

The 4 ha study sites were uniquely numbered, their boundaries mapped in the GIS, and then overlayed on aerial photographs and A4 maps were produced. GPS coordinates of the 4 corners were generated from these boundaries in Arc/Info and loaded into GPS units for easy identification of site corners in the field.

At the field site, each corner of the quadrat was marked with a wooden stake with coloured surveyors' tape attached. Each tree within the site was then numbered sequentially and permanently labeled using plastic cattle tags and galvanised iron nails. Tags were all attached on the same aspect of trees at each site for easy location by the bird observer. Each tree was marked and labeled on the A4 colour map to reflect its field number. This unique number was then transferred back to the paddock trees spatial point dataset using ArcView 8.2. A total of 897 individual trees (either isolated or overlapping as clumps) and 19 grouped clumps of trees were uniquely tagged and recorded in the 49 4ha sites.

Trees were deemed to be a clump if they overlapped by more than 10cm. When this occurred all trees in the clump were numbered using the next sequential number and then an, A, B, C etc to indicate that they were part of that same clump e.g. 10A, 10B. Clumps consisted of 2 or more trees that were overlapping. In a few cases clumps consisted of 10 or more trees. Each tree was given a unique number based on an amalgamation of the site number and its tree number e.g. 114712A, where 11471 is the site number and 2A is the tree number. For 19 of the clumps one or two trees in the clump were uniquely labeled and measured and then the remainder of trees in the clump were labeled using one unique tag and label identifier.

General site data was recorded. This included land use type, presence of tree regeneration, presence of timber, presence of litter, total number of trees (see Appendix I).

The following information was captured for each tree: Tree species; Height; Canopy Depth; Dieback%; Trunk rubbed; Canopy Diameter; Canopy overlap (where applicable); height of canopy from ground; number of trees in the clump (where applicable); bees in hollows; Trunk Diameter at Breast Height (DBH); Number of mistletoe individuals; %Canopy occupied by Mistletoes; Small Hollows (<10cm); Medium Hollows (10-15cm); Large Hollows (>15cm) (see Appendix I).

In the case of clumps where one or two trees were individually measured but the remainder were pooled as a unique record, the height of the tallest tree, average dieback for clump, total hollow count for clump were recorded only against this unique clump record on the datasheet.

Using this field data the following additional fields of actual canopy cover per tree or clump and canopy volume index per tree or clump were calculated.

Canopy cover (m^2) per tree or clump

This was calculated using the formula pie r^2 (area of a circle). Field diameter of the tree canopy was used for single trees to determine the radius. For clumps, if the overlap between trees had been estimated in the field then the total area was the 2 circles of canopy (minus the overlap) added together, if not, the area of the canopy was mapped in ArcView 8.2 on screen using the ortho-rectified photographs and the area calculated using the GIS.

Canopy Volume Index

For individual trees (those not in clumps) the formula for the area of a cylinder was used. A cylinder was used as this best represented the shape of the tree species being measured. The calculation was:

Where r = canopy diameter / 2

Pie r^2 x the canopy depth and x (100–dieback%/100).

For clumps, where the canopy overlap was estimated in the field for all trees in clumps:

Where r = canopy diameter minus overlap/ 2

Pie r^2 x the canopy depth x (100–dieback%/100) added together for all trees in clump

Where canopy overlap was not estimated in the field:

The actual area calculated in m^2 from photos x by the average canopy depth x average dieback of all trees in the clump (where clumps contained dead trees these were not included in the averages as they contained no canopy).

4.1.4 Field Survey: Remnant Sites Tree Data

Corner locations of the 4ha remnant sites were determined at these sites in the field.

General site data was recorded. This included: floristic description; structural classification (Heard and Channon, 1997); site type i.e. roadside, patch; understorey description; tree regeneration (see Appendix I).

Within the remnant sites, 5 of the largest trees were chosen from across the 4ha site, and data was collected and calculated for these in the same way as for the paddock tree sites. In total 125 individual trees in 25 remnant 4ha sites were tagged and their specific characteristics recorded (see Appendix I).

4.1.5 Bird Survey

The bird survey was conducted between late March and May (autumn) 2003. Paddock tree sites were observed for birds once during the afternoon and then on the following morning. At the beginning of the survey period for each site, birds on the ground were noted. Each tree within the site was visited in turn, with birds in the tree or leaving the tree noted. Birds flying over were also noted. There was no set time for the survey, but each tree was viewed for approximately the same time by the observer. A fixed time was not used as this would have meant that trees in sites with low tree numbers would have been watched for much longer than sites with many trees, and the bird survey effort would have been different. Generally the time spent was approximately 20 minutes. Birds moving from tree to tree were only recorded the first time they were seen. The method chosen was effectively a snap shot of the birds using each tree adapted from Paton and Eldridge (1994), and a fixed area with time related to the number of trees present, adapted from Loyn (1986).

Traditional bird survey methods used for remnant vegetation such as the variable circular plot method (point count) (Reynolds et al., 1980), transects (Recher et al., 1983;Bell and Ferrier, 1985), and time fixed methods (Loyn, 1986), were considered and tested. However these methods were not considered appropriate for the heavily modified paddock tree environment, where large spaces exist between trees, there are variable numbers of trees at each site, and overall there are low numbers of birds observed at sites. As the same bird observer collected all bird data issues of differences in time spent at trees was avoided. The issue of double counting birds was not considered an issue for the survey method due to the confidence and experience of the bird observer. Similar to the paddock tree sites, remnant sites were surveyed once in the afternoon and then on the following morning. An approximate 20 minute survey of these sites was undertaken. Bird species and their abundance at the remnant site were recorded.

4.1.6 Spatial Data Calculations

All spatial calculations were generated using customised AML programs generated for this project in ARC/INFO 8.2.

Canopy Cover

For each 4ha paddock tree site: Canopy Cover was generated using ARC/INFO by buffering tree points based on half its canopy diameter as measured in the field. This was classed as the actual cover, and used for all cover analyses, as opposed to the GIS generated cover based on the canopy averages of species (see Section 3.1.3). This was important, as there was considerable variation in the accuracy of the GIS generated cover versus the real cover of the site based on the field data collected. This meant that the canopy cover (using the average canopy diameter method) for each site changed once the real cover was calculated. The overall effect however did not considerably change the range or proportion of different cover amounts tested at these sites, just the actual cover that each site represented. Figures 8 and 9 show histograms of final site cover used for analysis, using the actual cover generated from field data.

For each individual tree within the 4ha paddock tree site: canopy cover for a 4ha square area around each tree was calculated, using the tree as the center point for generating the 4ha square cell. In order to generate real cover vs the GIS generated cover, each tree canopy within a 200m buffer of the 4ha paddock tree site was measured on screen in ArcView 8.2 and the diameter recorded against the tree. Actual canopy cover was then calculated in the same way as for the 4ha fixed sites.

Landscape Cover

It wasn't possible to individually measure each tree canopy diameter in the mapped dataset to generate a completely accurate version of canopy cover. Hence the GIS generated canopy cover data set (based on the average canopy cover per species) was used to determine the % of cover around each of the 4ha paddock tree sites for the landscape scale analyses. Cover within a 500m, 100m, 2000m and 5000m radius was calculated.

Distance to nearest remnant vegetation block

For each 4ha paddock tree site: Distance from the centre of the 4ha cell to the nearest block of 1ha, 20ha and 80ha was determined using an automated program in Arc/Info.

For each individual tree within the 4ha paddock tree site: Distance to the nearest block of 1ha, 20ha and 80ha was determined using an automated program in Arc/Info.

4.1.7 Student field studies

A University Honours project to supplement field based findings for this project was undertaken over July 2002 to June 2003. This project examined the influence of distance of paddock trees from moderately sized woodland patches (greater than 5 ha) and assessed whether use of paddock trees by birds varies with distance from the nearest remnant patch (Orr, 2003). The abstract can be found in Appendix II.

4.1.8 Statistical Analysis

For each site and individual tree, bird species richness, species diversity and bird density were calculated. At the site level this included birds recorded on the ground within the site. Species flying over were excluded from all calculations.

Species Diversity

Diversity was calculated using the Shannon Diversity Index:

H = - sum pi log pi

Where pi = ni/N

That is, pi is the proportion of the total number of individuals occurring in species i (Brower et al., 1989).

Functional Groups

Bird species were grouped into 3 broad categories representing their habitat preferences, rather than the particular guilds they belonged to (Table 11). This was based on an assessment of how well distributed particular species were recorded across the different % cover sites. Scatter plots for each species at paddock tree sites, showing species abundance versus % cover were created. . Using a general rule that 1/3 of the sites were 6% cover and below (0.25 to 4 trees/ha), 1/3 were between 6 – 12% cover (1.7 to

12.5 trees/ha), and 1/3 above 12% cover (3.3 to12.5 trees/ha), species were assigned a group depending on where the majority of their sightings occurred with regard to site cover (see Appendix III). Only those species that were present at 3 or more sites were included. The birds in group1 are defined as those requiring native woodlands (Simpson and Day, 1999) and whose habitats extend into paddock trees. Species included in this group were Blue-faced Honeyeater, Grey Fantail, Jacky Winter, Laughing Kookaburra, Mistletoebird, and Rufous Whistler. Group 2 birds are defined as those that live in eucalypts, even if the understorey is cleared, and are predominantly tree canopy feeders, including mobile nectar feeders. These included Striated Pardalote, Rosellas, Lorikeets, Cockatoos, and some of the more abundantly recorded honeyeaters such as White-naped, White-plumed, and Yellow-faced Honeyeaters, Red Wattlebird and Noisy Miner. Group 3 birds are defined as generalist species or open country feeding species, and they included Australian Magpie, Forest Raven, Long-billed Corella, Welcome Swallow and others. Species were also defined as honeyeaters, small birds, hollow nesters, foliage-gleaners and bark feeders (Table 11).

Multiple Linear Regression, Analysis of Variance and Chi-squared Tests

BiometricsSA, a statistical consulting group from the University of Adelaide, were contracted to undertake the statistical analysis of the bird related field data. BiometricsSA were also involved in providing advice with regards to the statistical validity of the study design at all stages of the project. A comprehensive report explaining the statistical methods and results for this study is provided in Lorimer (2003).

To determine which factors were related to the use of paddock trees by birds at the site and landscape levels, multiple linear regression (MLR) and Analysis of Variance (ANOVA) methods were used. MLR determines the influence of various explanatory variables associated with the paddock tree sites, for example cover and vegetation type, on individual response variables such as bird density or species richness or species diversity. MLR involves determining statistically which of the explanatory variables are important (significant) and which are not important (non-significant) in predicting the value of the response.

The significance of each explanatory variable is tested using backward elimination. This involves fitting a model containing all the explanatory variables then dropping each variable in turn and assessing the significance of each until only the explanatory variables left in the model are those which have a significant affect on the response. Significance of all explanatory variables is usually tested at the 5% level, so that a p-value of less than 0.05 would indicate a significant explanatory variable. For this study, terms that were marginally significant were included in the model as they were considered to have importance from an ecological perspective as an indication of possible relationships. If the p-value was greater than 0.10 then the explanatory variable was dropped from the model. The final model included the variables of site cover, total number of site hollows, distance to nearest 20ha remnant patch, the % of native vegetation within 2km radius, the square root of the total number of trees, and the vegetation type.

An indication of how well the model is explaining the relationship between the response and explanatory variables is given by the adjusted coefficient of determination or R^2. High percentages indicate the model is fitting well and most of the variation in the response is explained by the explanatory variables. Low percentages indicate the model is not fitting well and there is unexplained variation in the response. This suggests that further variables, which may have not been recorded, have also impacted on the response.

Table 11 Functional Bird Groups

Group	Birds
Group 1 Birds that require native woodlands or forests, whose distributions extend into scattered trees (degraded woodlands) These species had proportionally more sightings in the > 6% cover sits and few if any in < 6% cover sites	Blue-faced Honeyeater, , Grey Fantail, Jacky Winter, Laughing Kookaburra, Mistletoebird, Rufous Whistler
Group 2 Birds that live in eucalypts and are predominantly tree canopy feeders (includes mobile species that feed on nectar), even if understorey is cleared These species had proportionally more sightings in the > 6% cover sites but some in < 6% cover sites	Black-faced Cuckoo-shrike, Crimson Rosella , Eastern Rosella, Musk Lorikeet , Noisy Miner, Rainbow Lorikeet , Red Wattlebird, Striated Pardalote, Sulphur-crested Cockatoo, White-naped Honeyeater, White-plumed Honeyeater, Yellow-faced Honeyeater
Group 3 These are open country species or generalists. These species had sightings proportionally evenly spread across all sites, regardless of % cover.	Australian Magpie, Common Starling, Forest Raven, Galah, Little Raven, Long-billed Corella, Red-rumped Parrot, Welcome Swallow, Willie Wagtail, Yellow-rumped Thornbill
No Group Species recorded at 2 or less scattered tree sites (excluded from group analysis)	Australian Raven, Brown-headed Honeyeater, Crested Pigeon, European Goldfinch, Golden Whistler, Grey-shrike Thrush, Magpie-lark, New Holland Honeyeater, Purple-crowned Lorikeet, Restless Flycatcher, Silvereye, Spotted Pardalote, Varied Sittella, White-fronted Honeyeater, White-fronted Chat, Yellow Thornbill
Honeyeaters	Black-chinned Honeyeater, Brown-headed Honeyeater, Blue-faced Honeyeater, New Holland Honeyeater, Red Wattlebird, Tawny-crowned Honeyeater, White-fronted Honeyeater, White-naped Honeyeater, White-plumed Honeyeater, Yellow-faced Honeyeater
Small birds	Brown Thornbill , Buff-rumped Thornbill, Mistletoebird, Restless Flycatcher, Silvereye, Spotted Pardalote, Striated Pardalote, Striated Thornbill, Superb Fairy-wren, Tree Martin Varied Sittella, White-fronted Chat, Yellow Thornbill, Yellow-rumped Thornbill
Birds recorded only in High Cover Sites	Black-chinned Honeyeater, Brown Falcon, Brown Thornbill, Brown Treecreeper, Buff-rumped Thornbill, Common Bronzewing, Crested Shrike-tit, Dusky Woodswallow, Grey Currowong, Little Wattlebird, Striated Thornbill, Superb Fairy-wren, Tawny-crowned Honeyeater, Tree Martin, Wedge-tailed Eagle, Weebill, White-bellied Cuckoo-shrike, White-browed Babbler, White-throated Treecreeper, White-winged Chough
Bark Feeders	Black-chinned Honeyeater, Blue-faced Honeyeater, Crested Shrike-tit, Noisy Miner, Red Wattlebird, Varied Sitella, White-throated Treecreeper
Hollow Nesting	Blue-winged Parrot, Brown Tree Creeper, Common Starling, Dusky Woodswallow, Eastern Rosella, Galah, Laughing Kookaburra, Long-billed Corella, Musk Lorikeet, Peregrine Falcon, Purple-crowned Lorikeet, Rainbow Lorikeet, Red-rumped Parrot, Striated Pardalote, Sulphur-crested Cockatoo, Tree Martin, White-throated Treecreeper
Foliage Feeders	Black-chinned Honeyeater, Black-faced Cuckoo-shrike, Blue-faced Honeyeater, Brown-headed Honeyeater, Buff-rumped Thornbill, Crimson Rosella, Eastern Rosella, Golden Whistler, Grey Fantail, Grey Shrike-thrush, Musk Lorikeet, New Holland Honeyeater, Noisy Miner, Olive-backed Oriole, Red Wattlebird, Restless Flycatcher, Rufous Whistler, Silvereye, Spotted Pardalote, Striated Thornbill, Weebill, White-bellied Cuckoo-shrike, White-naped Honeyeater, White-plumed Honeyeater, Yellow Thornbill, Yellow-faced Honeyeater

ANOVA was used to determine for paddock tree sites, whether there was an interaction between vegetation type and Noisy Miner presence or absence, for the level of cover. ANOVA was then used to determine whether there were significant differences between Noisy Miner sites and differences in vegetation types in relation to species diversity.

Bird groups of honeyeaters and small birds were defined (Table 11) in order to test whether their presence or absence was affected by the presence of Noisy Miners. To investigate this, the number of sites that might expect to contain a Noisy Miner and either a bird from the honeyeater group or the small bird group were compared with the number of sites at which both types of birds were actually observed. A chi-squared test was used to test whether the observed and expected frequencies of Noisy Miners and honeyeaters or small birds are equal. If they are, then the presence of Noisy Miners would appear to have no affect on these other birds.

To compare the remnant sites with paddock tree sites, ANOVA was used to test whether there was an interaction between vegetation type and type of site in relation to species richness, or the number of group 1, group 2 or group 3 individuals.

4.2 Field Study Results

4.2.1 Landscape Calculations

The maximum variation in distances from 4ha paddock tree sites to nearest remnant vegetation patch of 1ha, 20ha and 80ha, and for the amount of native vegetation within a 1km, 2km and 5km radius are shown in Table 12.

Table 12 Range of landscape calculations for paddock tree sites

	Distance to 1ha vegetation patch	Distance to 20 ha vegetation patch	Distance to 80 ha vegetation patch	Native Vegetation within 1km radius	Native Vegetation within 2km radius	Native Vegetation within 5km radius
Red Gum	200m -509m	200m – 4,817m	200m – 11,293m	3.7% - 25%	2.8% – 24.7%,	2.9% - 15.6%
Blue Gum	216 – 450m	216m – 1235m	218m – 4,594m	6.3% - 28.4%	4% - 26.8%,	7.1% - 12.7%

4.2.2 Tree characteristics

Dieback

Table 13 shows the breakdown of the dieback results from all trees surveyed, both as a % of total trees for the paddock tree and remnant sites, and as a breakdown based on the three main eucalypt species surveyed in the paddock tree sites of Red, Blue and Pink Gum. No tree species had more than 10% of its trees with dieback greater than 33%, while 40% of Red and Blue Gums and 28% of Pink Gums had negligible dieback (Figure 11). Significantly 4% of Pink Gums had dieback greater than 66%, indicating that for this tree species dieback that will likely progress to tree death will have a serious impact on the long term survival of the total population.

Hollows

Table 14 shows the breakdown of the number of hollows found in all trees surveyed. Table 15 shows a breakdown of the presence of hollows per Red, Blue and Pink Gum trees.

Table 13 Dieback recorded in Paddock Trees

	Scattered Tree Sites				High Cover Sites
Dieback %	**Red Gum %of total (253)**	**Blue Gum % of total (274)**	**Pink Gum % of total (226)**	**All Species %of total (878)**	**All Species % of total (125)**
negligable (i.e. < 5%)	40	39.8	27.8	33.8	34.4
>= 5% <= 33% (Low)	57	56.6	62.4	53.5	50.4
>33% <= 66% (Meduim)	2.7	2.9	5.7	4.6	9.6
>66% < 100% (High)	0	<1	4	1.6	2.4
Dead	n/a	n/a	n/a	6.5	3.2

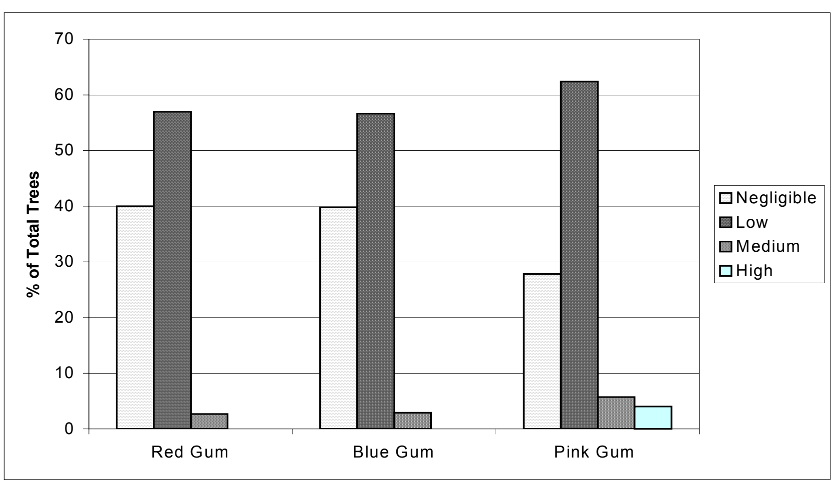


Figure 11 Dieback measures in Paddock trees for Red, Blue and Pink Gum

Table 14 Total hollows from all sites

		Number of Hollows			
	Number of Trees	Total	Small	Medium	Large
Live	279 of 942 (30%)	889	407	278	204
Dead	33 of 61 (51%)	130	59	34	37

Table 15 **Hollows from all sites for Pink, Blue and Red Gum only**

		Number of Hollows			
	Number of Trees	Total	Small	Medium	Large
Pink Gum	48 of 237 (20%)	122	69	29	24
Blue Gum	86 of 316 (27%)	245	123	72	50
Red Gum	124 of 316 (39%)	457	169	163	125

DBH and total numbers of visible hollows including small, medium and large have been plotted for Blue, Red, and Pink Gums surveyed (Figures 12,13 and 14). From the scatter plots it is evident that for Red Gums, visible hollows start at a DBH of 60cm and continue through to 340cm, for Blue Gums they start at a DBH of 60cm and continue through to 190cm, and for Pink Gums they start at 50cm and continue through to 140cm. The maximum number of visible hollows recorded in a Red Gum was 17, with a 260cm DBH, for Blue Gum it was 10, in trees with a 60cm and 140cm DBH, and for Pink Gum, it was 10 in a tree with a 90cm DBH. For Red Gum 39% of trees surveyed contained at least one visible hollow, for Blue Gum 27% of trees surveyed, and for Pink Gum, it was 20%. The differences in DBH range for each species reflects the natural size of these trees, Red Gums being the naturally largest and Pink Gums the smallest. Not all trees with large DBH's will necessarily contain hollows however the larger the DBH the more likely it will contain a hollow.

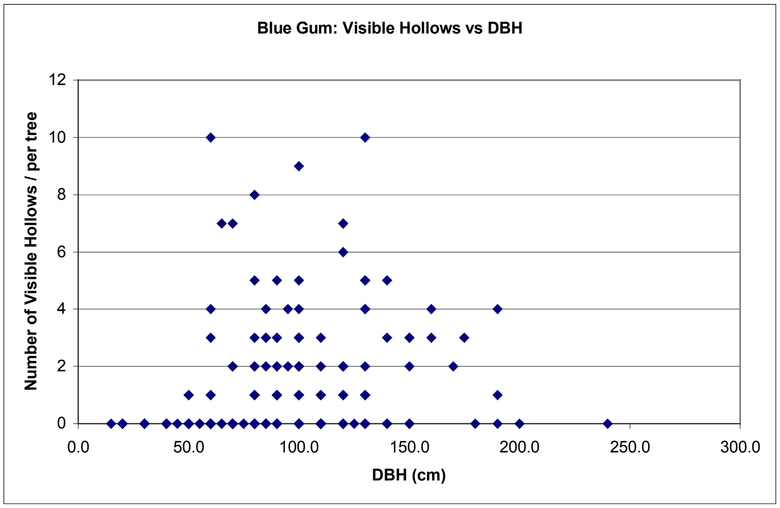


Figure 12 Hollows vs DBH in Blue Gum Trees

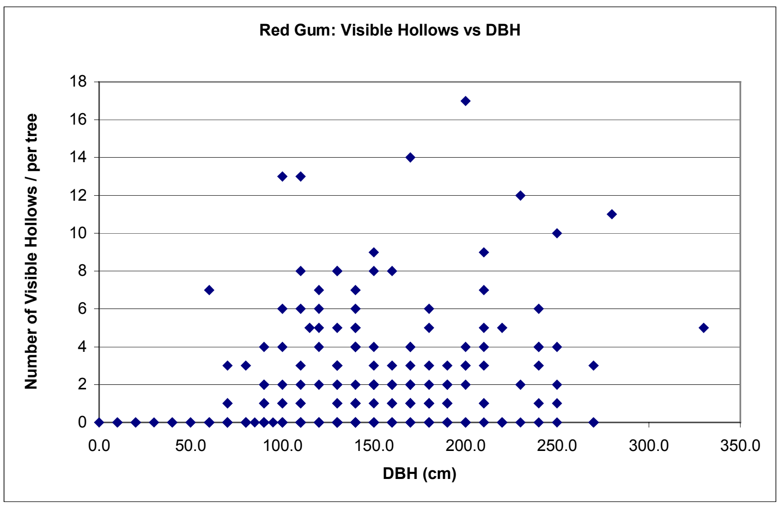


Figure 13 Hollows vs DBH in Red Gum Trees

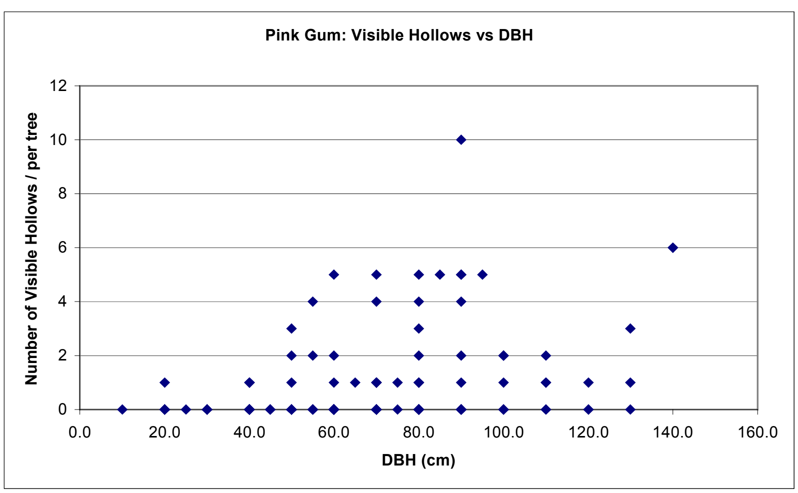


Figure 14 Hollows vs DBH in Pink Gum Trees

4.2.3 Bird Survey Results

Species Composition in Paddock trees and Remnant Sites

A list of all the bird species recorded at both paddock tree and remnant sites is listed in Appendix IV. The overall results were as follows (excludes species observed flying over):

- 67 species were recorded in all 4 ha sites (both paddock tree and remnant)
- 45 species were recorded in paddock trees sites
- 64 species were recorded in remnant sites
- 42 species were common to both paddock tree sites and remnant sites
- 2 species were exclusive to paddock tree sites
- 22 species were exclusive to remnant sites

Of the 878 unique paddock trees surveyed for bird use at the paddock tree sites, the results of the observations in individual trees was as follows:

- 231 (26%) trees had birds recorded in the first (afternoon) visit.
- 324 (37%) trees had birds recorded in the second (morning) visit.
- 304 (35%) trees had birds recorded in only 1 visit out of 2.
- 126 (14%) trees had birds recorded in both visits.
- 430 (49%) trees had birds recorded in them after the second visit.

Regional Perspective

A database search for all officially recorded bird species within the field survey study area (coordinates MGA Zone 54, Eastings 475941 – 495941, Northings 5881799 – 5940199) revealed a total of 186 bird species with an additional 2 recorded on the current survey. The Biological Databases of SA as of 14th October 2003 contained 132 species, with an additional 54 recorded in the Birds Australia Database 2001. The two additional species recorded on the current survey were the Olive-backed Oriole, recorded in a Red Gum Woodland in Glen Roy Conservation Park, rated as Extinct for the region, and the Blue-winged Honeyeater, recorded in both paddock trees and remnant sites, with an SA status of Rare (Croft and Carpenter, Unpublished). Water birds (45) were removed from this total as survey sites were located away from water, and the survey was conducted in Autumn following a dry winter, spring and summer. The total number of officially recorded bird species for the study area excluding water birds was 141. The total number of bird species recorded using paddock trees or remnant sites from the survey represented 46% of bird species recorded for the total area. The number of bird species recorded using paddock trees represented 32% of the total species for the area.

Site Relationships with Bird Use

Total Birds – Paddock Tree Sites

The model for total birds (density) (R^2 = 31%) indicates a significant interaction between site cover and timber at the 5% level (p=0.014, MLR). Therefore, the total number of birds at a site is dependent on the amount of site cover and the level of timber. The final results suggest that the total number of birds increase as site cover increases, if the site has low timber on the ground. For sites with medium timber, the total number of birds decreases as site cover increases, although the slope for this predictive equation was approaching 0 (0.0002). This indicates that cover has no real effect on bird density at medium timber sites.

Species Richness – Paddock Tree Sites

The model for species richness (R^2 = 34%) indicates a significant interaction between timber and vegetation type (p=0.03, MLR) and a marginally significant interaction between site cover and timber (p=0.06, MLR). The final results suggest that species richness increases as site cover increases, if the site is a low timber site, regardless of vegetation type. If the site has medium timber then species richness decreases as site cover increases for both vegetation types.

Species Richness – Paddock Tree vs Remnant Sites

There is no significant difference at the 5% level in species richness, on average, between Red Gum and Blue Gum sites (p=0.15, ANOVA). There is, however, a significant difference in species richness between high cover and paddock tree sites ($p<0.001$, ANOVA), with significantly more species, on average, observed in high cover sites compared to those observed in the paddock tree sites.

Species Diversity – Paddock Tree Sites

This model for species diversity (R^2 = 41%) showed a marginally significant positive interaction between Site Cover and Vegetation Type (p=0.06, MLR). Site cover appears to influence diversity more at Blue Gum/Pink Gum compared to Red Gum sites.

Group 1 Birds

For paddock tree sites the number of group 1 birds sighted during the survey was limited and hence statistical analysis revealed no correlation with site cover or any of the other model variables. However, of the 18 paddock tree sites where group 1 birds were recorded, only 2 sites were below 6% cover (Figures 15 and 16), indicating that when group 1 birds were present, the sites were more likely to be at higher cover sites of 6% or more. For remnant versus paddock tree sites, the main effect for vegetation type is not statistically significant (p=0.928, ANOVA). However, it can be concluded that the average number of group 1 individuals is significantly different between remnant and paddock tree sites ($p<0.001$, ANOVA). Results indicate that the group 1 birds were more abundant at remnant sites than paddock tree sites.

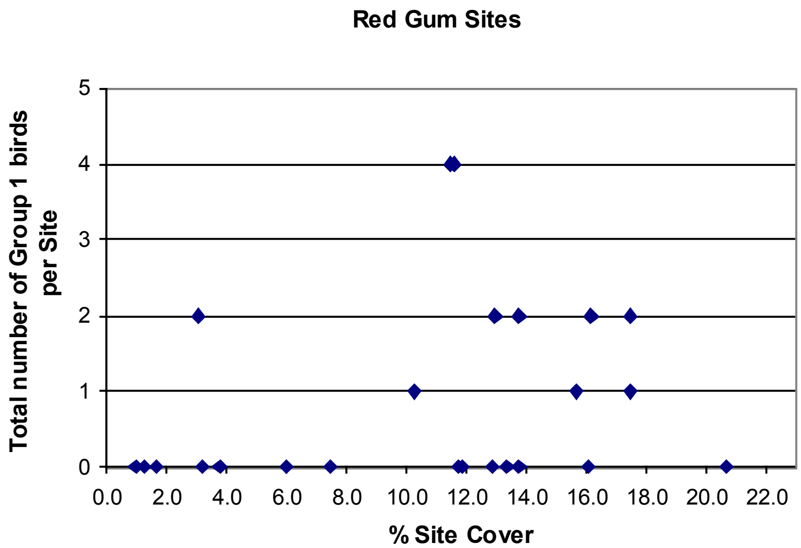


Figure 15 ***Group 1 birds and % Site Cover for Red Gum 4ha Paddock Tree Sites***

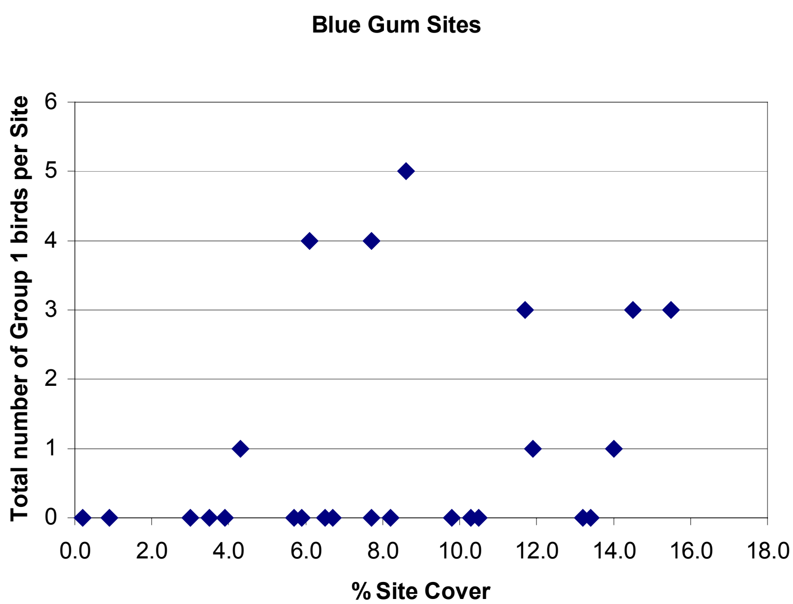


Figure 16 ***Group 1 birds and % Site Cover for Blue Gum/Pink Gum 4ha Paddock Tree Sites***

Group 2 Birds

For paddock tree sites this model (R^2 = 43%) showed the interaction between site cover and vegetation type is marginally significant (p=0.08, MLR). The results suggest that group 2 birds demonstrated an increased abundance as cover increased at both Red Gum and Blue/Pink Gum paddock tree sites, however the rate of increase was much smaller for Red Gum sites. For remnant versus paddock tree sites, the results indicate that the main effect of vegetation type and the main effect of type of site are both statistically significant at the 5% level (p=0.004 and p=0.004, ANOVA, respectively). These birds were more abundant in the remnant sites compared to paddock tree sites, and were more abundant at Blue Gum/Pink Gum sites compared to Red Gum sites.

Group 3 Birds

For paddock tree sites this model (R^2 = 26%) indicates that no interactions of variables are significant at the 5% level. For remnant versus paddock tree sites the results suggest that the abundance of group 3 individuals in high cover sites is not significantly different to that of paddock tree sites. However, the main effect for vegetation type is statistically significant at the 5% level (p=0.017, ANOVA). This result indicates that these birds were more abundant in the Red Gum sites compared to Blue Gum/Pink Gum sites.

Hollow Nesters, Bark-feeders and Foliage-gleaners

Hollow nesters, bark-feeders and foliage-gleaners were analysed for paddock tree sites only. Results indicate that the abundance of hollow nesters (p=0.04, MLR), bark-feeders (p=0.02, MLR) and foliage-gleaners (p=0.06, MLR, marginally significant) increased as site cover increased. For bark-feeders and foliage-gleaners the effect of the increase was greater at Blue Gum than at Red Gum sites.

Noisy Miners

Noisy Miners were found at 19 (39% after 2 visits) of the 4ha paddock tree sites and with 76 individuals sighted in individual trees. No relationship between site cover or vegetation type and the presence of Noisy Miners was found. For the purpose of comparative analysis with another paddock tree study conducted in the same area (Orr, 2003). Honeyeaters and small birds were grouped separately (Table 11) and compared with the presence or absence of Noisy Miners. The expected value for the number of 4ha sites that Noisy Miners were recorded in, along with another bird in either the honeyeater or small bird group, was compared with the observed values. No significant differences were found between observed and expected sightings for either group, when Noisy Miners were present at the site level.

Noisy Miners were found at 16 (62% after 2 visits) of the remnant sites with 93 individuals sighted. No significant differences between observed and expected sightings for either honeyeaters or small birds, when Noisy Miners were present, for the remnant sites.

The analysis of cover with vegetation type and Noisy Miner found no significant interaction for vegetation type (p=0.18, ANOVA). Cover is also not statistically significant at the 5% level (p=0.26, ANOVA) indicating that the average level of cover is not significantly different between Noisy Miner and non-Noisy Miner sites. The analysis for diversity with vegetation type and Noisy Miner sightings found no significant interaction for vegetation type (p=0.62, ANOVA), indicating that the vegetation type is not significant between Noisy Miner and non Noisy Miner sites. There is however a significant difference between sites containing Noisy Miner and those that were absent of Noisy Miners (p=0.001, ANOVA). Results indicate that diversity is on average higher in sites with noisy miners compared to sites without noisy miners.

5 MAPPING TRANSFERABILITY AND REMOTE SENSING

5.1 Image Processing and Transferability

The decision to map the Tintinara study area using a similar mapping method to the South East study area was based on the need to further refine and test the digitising approach in an area with different plant community structural types and therefore canopy cover. This was so the digitising method would be transferable to other areas of Australia, particularly across the Murray-Darling Basin, where paddock trees may require mapping. The main advantages of the digitising method over all other methods are: the positional accuracy of tree location mapping, and the accuracy of actual mapping i.e. based on human interpretation of photographs. The main problems have been identified as time and staff resources to undertake the work, the cost of image purchase and digitising, and small inaccuracies in the conversion of point data to cover data.

The main question that should determine whether a particular mapping method is used is will the data be suitable for decision making?

To answer this we need to consider:

- What scale will decisions be made at? i.e. property, local, regional;
- How strict are the specifications for management? e.g. number of trees on a particular property versus a general amount of tree cover;
- The limitations the method will create in the dataset and how this will affect its use i.e. a vegetation category may include all native and non native vegetation;
- The usefulness/limitations of any existing datasets.

In summary, the detail required of a dataset (on which decisions will be based) will determine the scale of mapping and the level of error that is acceptable, including both actual and interpretive error.

For practical reasons of costs, timing and expertise it was not possible to undertake work to map the South East and Tintinara study areas using a different mapping method, such as remote sensing. In addition to this, substantial work has been undertaken in both Victoria and NSW in this field. The remote sensing technique using SPOT4 Panchromatic imagery has been used in Victoria (Department of Natural Resources and Environment, 1999) to map tree cover across the State. A similar has also been used in NSW (Gibbons and Boak, in press) to investigate the importance of paddock trees in relation to total vegetation cover. SPOT4 offers many advantages over ortho-rectified aerial photography. SPOT4 imagery is readily available over all of Australia, is cheaper and covers much larger areas at better temporal frequency than aerial photography. However, the lower resolution of this satellite imagery may be insufficient for mapping paddock trees, particularly in areas of low cover or areas with small tree canopies.

Tree cover mapping data existed from the Victorian tree cover mapping dataset over two partial 1:25,000 mapsheets of the South East study area in SA. As a result we were able to directly compare the results of the two different methods with regards to accuracy of paddock tree cover mapping. Key issues with a tree cover dataset generated using SPOT4 Panchromatic Imagery were expected to be the spatial resolution of the imagery itself and; the separation of paddock tree cover from ‘other’ cover. The disadvantages were therefore expected to include the limiting factor of 10m pixel size which would miss trees with canopies smaller than 7-8 m and/or trees with canopies that have percent foliage cover of less than possibly 70% (i.e. trees exhibiting signs of dieback) and the misclassification of cover.

5.1.1 Victorian Tree Cover mapping

The Victorian TREE25 layer provides a statewide coverage of tree cover for Victoria. This was mapped using SPOT4 Panchromatic Satellite Imagery (10m pixels) by a combination of digital classification and visual interpretation. The dataset depicts the presence/absence of tree cover (Department of Natural Resources and Environment, 1999). No estimate of error has been calculated for the dataset (Pers.com. Michael Conroy, Victorian Department of Sustainability and Environment August 2003). The SPOT4 images were taken in December 1995 and December 1996.

5.1.2 Comparison of SA and Victorian Tree Cover Mapping

In order to test the variability of these 2 mapping techniques an area of 46,380 ha in SA that had been mapped using both techniques has been compared. This comparison assumes the digitising method to be the most accurate, with GIS generated cover predicted in most cases to be well correlated with real cover (see Section 3.2.5). Measurements that were specifically important to determine where:

- the overall amount of (paddock) tree cover mapped by both methods;
- overall amount of non-native tree cover mapped by both methods;
- how many individual trees were 'missed' in the SPOT mapping;
- to quantify the extent to which the datasets differed in how individual trees or small clumps of trees (i.e. 1-3) were being mapped;
- to quantify the actual canopy cover density (i.e. % canopy cover over a fixed area) of the trees that were mapped by both methods.

As the two datasets were at most 2 years different, the effect of tree loss over this period in affecting the mapping was considered to be small. Visual comparison of the two datasets revealed the following issues with the SPOT4 dataset:

- Individual isolated trees were often missed;
- Trees with small canopies i.e.8m (e.g. Buloke) were missed;
- Trees in irrigated paddocks were not consistently mapped, with many missed;
- House trees, planted windbreak or fenceline trees, and wet areas, were all included as tree cover and could not be differentiated from true native paddock tree cover and removed from the dataset;
- There appeared to visually be an over or underestimate of tree canopy size in many cases – a function of 10m cell over a smaller 5m cell size, i.e. individual trees looked like square or rectangle blocks rather than a circular shape;
- The larger grid size (i.e.10m cells) seemed to cause a shift in individual tree cover, and generalised the cover more than the smaller grid size (i.e.5m cells).

In order to determine how different the paddock tree cover mapped in both datasets was, both were processed in the same way. The datasets were masked with existing layers to remove as much non paddock tree cover as was possible for both datasets. This included extant native vegetation in blocks greater than 1 ha (including some roadsides, road reserves and creekline vegetation), and roadsides were buffered by 20m either side. This ensured the comparison focused on the paddock tree mapping component of both methods.

Tree cover was calculated for both datasets. The SPOT4 dataset included all vegetation with no discrimination of native and non-native. The digitised dataset of tree cover was calculated in 2 ways. Firstly, with all tree cover mapped including house trees and windbreak trees. Secondly with only the native trees included i.e. paddock trees, roadside reserve trees (points), creekline trees (points), and clumps of paddock trees mapped as polygons. The results of the comparison in cover between the two datasets are shown in Table 16. When all native and non-native trees where included in both datasets, the SPOT4 dataset mapped an extra 10ha (1.5%) of tree cover. When the non-native component was removed from the digitised dataset and cover calculated again, the SPOT4 dataset mapped an extra 117ha (17.5%) of tree cover. This overestimate would be expected to increase with an increase in revegetation in an area.

Next, tree cover patch sizes were determined, using the same method outline in Section 3.1.4. Where a "patch" was defined as any area with a cohesive canopy area of greater than or equal to 25 m^2 (5 m by 5 m, or one cell) and greater than 5 m from adjacent woody vegetation.

Table 16 Tree Cover Comparison of the Digitised and SPOT4 Tree Cover Datasets

Mapping Method	Type of Cover	Total Cover (Ha)
SPOT Panchromatic Remote Sensing	native + non native trees (excludes roadsides + extant native vegetation blocks > 1ha)	672
Point digitising from Ortho-rectified aerial photography	native + non native trees (excludes roadsides + extant native vegetation blocks > 1ha)	662
	native trees only (includes road reserves, mapped clumps, creekline trees)	555

Table 17 Digitising method paddock trees only (excluding extant native vegetation blocks > 1ha and roadsides)

Size Category	#Patches	%Total Patches	Ha	%Total
le 0.04 ha	4557	25.8	**53**	9.5
gt 0.04 and le 0.06 ha	10383	58.7	287	51.6
gt 0.06 and le 0.1 ha	1575	8.9	81	14.6
gt 0.1ha and le 0.5 ha	1151	6.5	120	21.6
gt 0.5ha < 1ha	27	0.2	13	2.3
gt 1ha	2	0.0	**2**	0.4
Total	17695		556	

Table 18 Digitising method non native + native vegetation (excluding extant native vegetation blocks > 1ha and roadsides)

Size Category	#Patches	%Total Patches	Ha	%Total
le 0.04 ha	4604	25.2	**53**	8.0
gt 0.04 and le 0.06 ha	10533	57.6	292	44.2
gt 0.06 and le 0.1 ha	1654	9.1	85	12.9
gt 0.1ha and le 0.5 ha	1372	7.5	156	23.6
gt 0.5ha < 1ha	83	0.5	40	6.1
gt 1ha	28	0.2	**35**	5.3
Total	18274		661	

Table 19 SPOT4 method non native + native vegetation (excluding extant native vegetation blocks > 1ha and roadsides)

Size Category	#Patches	%Total Patches	Ha	%Total
le 0.04 ha	9113	54.7	**118**	17.6
gt 0.04 and le 0.06 ha	3067	18.4	86	12.8
gt 0.06 and le 0.1 ha	2759	16.6	128	19.0
gt 0.1ha and le 0.5 ha	1619	9.7	196	29.2
gt 0.5ha < 1ha	78	0.5	38	5.7
gt 1ha	30	0.2	**106**	15.8
Total	16666		672	

Using the digitised dataset as the baseline, it is possible to determine where the majority of the difference between the two mapping techniques exists, and hence the likely error in the SPOT4 method used. There are four key results from this comparison.

1. In the SPOT4 dataset small patches of 1 -2 trees (i.e. less than 0.04ha (20mx20m)) have been overestimated by approximately 223%. Where the digitised native plus non-native dataset totalled 53ha in patches less than or equal to 0.06ha, versus 118ha in the SPOT4 dataset (Tables 18 and 19). The overestimate of mapping of patches less than 0.04ha in the SPOT4 dataset can be explained through visual overlay of both datasets. In many cases, where 2 trees are near to each other, 1 will be missed in the SPOT4 dataset, putting this patch in the smaller <0.04ha category, whereas in the digitised dataset, the trees have been placed in the <0.06ha category. In addition, as the canopies are poorly defined in the SPOT4 dataset, due to the original 10m cell size, there is sometimes less canopy mapped for an individual tree, again putting the same tree into the smaller patch size category for the SPOT4 dataset, and the larger patch size category for the digitised dataset. The ability of the digitised dataset to map much finer spatial representation of individual trees is a function of the 5m grid cell used for original processing.

2. In the SPOT4 dataset small patches of 1 – 3 trees (i.e. less than 0.06ha (25mx25m)) have been underestimated by approximately 40%. Where the digitised native plus non-native dataset totalled 345ha in patches less than or equal to 0.06ha, versus 204ha in the SPOT4 dataset (Tables 18 and 19).

3. When the two versions of the digitised dataset are compared (Tables 17 and 18), i.e. native only versus native and non native, there is virtually no change in amount of tree cover in the patches less than 0.1ha (32mx32m). This would indicate that discrimination of tree cover between native and non-native is not an issue when mapping individual or small clumps of paddock trees.

4. The majority of the overestimate of tree cover in the SPOT4 dataset appears to be in the larger than 1 ha paddock tree patches, where non-native tree cover and non-tree cover is probably being mapped. The overestimate of 'extra' mapping is 302%. Where the digitised native plus non-native dataset totalled 35ha in patches greater than 1 hectare, versus 106ha in the SPOT4 dataset (Tables 18 and 19). Based on this result, if we remove the additional 71ha from the SPOT4 datasets cover in the >1ha patches, and recalculate the amount of tree cover from table 19, there is an underestimate of mapped tree cover of 10%. This underestimate increases to 40% at the less than 0.06ha patch size.

An important result from the comparison is that at an overall paddock tree cover level, the overestimate of total paddock tree cover for the SPOT4 method was just 1.5%. This average error is misleading as it is the result of the evening out of an overestimate in the larger 1ha patches and an underestimate in smaller patches. In the NSW study, which used SPOT4 Panchromatic imagery also, the overall error in the tree cover mapping (including paddock trees and all remnant vegetation blocks) was estimated at an 11% overestimate (Gibbons and Boak, in press). Again, this error estimate is possibly too general to be useful, and the NSW study points out that the dataset is indicative of average patterns across the landscape only, and not an exact depiction of tree cover in all areas (Gibbons and Boak, in press).

Possibly the most important error detected in the SPOT4 mapping method is an underestimate (40%) of tree cover in patches less than 0.06ha. As these are the bulk (85%) of the isolated or small clumps of paddock trees, it is important that they are being missed or underrepresented by the SPOT4 mapping technique.

General descriptive limitations of the SPOT4 method would therefore include:

- poor paddock tree cover mapping in regions where plant communities contain overstorey tree species with canopy diameters less than 10m, or trees with canopies suffering the effect of dieback and therefore canopy thinning;
- regions where paddock tree cover was particularly low;
- the inclusion and therefore misrepresentation of planted tree cover as paddock tree cover;
- an inability to provide accurate canopy cover mapping at a property level for the above mentioned reasons;
- overestimation of bare paddock space due to missed mapping of individual trees.

Advantages of the SPOT4 method over the digitising method include the large cost reduction, and ease of processing, of this method. The digitising method however, appears to produce a more accurate dataset, both with regard to mapping of individual trees, and mapping their actual canopy cover, than the SPOT4 Remote Sensing technique.

6 DISCUSSION

6.1 Mapping

One of the most important findings of this study is that paddock trees represent an important and unrecognised component of vegetation cover in both areas, which should not be left unaccounted for in landscape conservation planning. Both study areas represent highly cleared agricultural areas, where paddock tree cover contributes up to 25% of total native vegetation cover. In both areas the majority of mapped trees (85% for the South East and 90% for Tintinara) were found in patches of less than 0.06ha (25m x 25m). This result indicates that a majority of paddock trees exist as single trees or small groups of trees in the landscape separated by gaps greater than would have existed prior to European settlement. This situation leaves them vulnerable to clearance and to the detrimental effects of agricultural practices, most of which are incidental e.g. soil compaction, fertiliser drift, physical damage by stock, stubble burning, exposure through increased isolation and therefore to increased risk of dieback.

Past vegetation clearance in these regions has been selective, with some plant communities much less represented in the remaining plant community mix than others. Typically, these are the woodland communities found on more productive agricultural soils, and remnancy estimates for most are close to 10%, theoretically rating them as vulnerable, while some could be rated as threatened (less than 3%) (Croft et al., 1999). This disproportional clearance is reflected by the presence of paddock trees in the landscape that represent these former woodland communities. For example in the Red Gum Woodland community of the South East, paddock tree cover accounts for 35% of the total vegetation cover for that community, and for Blue Gum and Pink Gum Woodlands, it accounts for 13.5%. In the Tintinara study area the contrast is even more distinct. For ten of the twelve plant communities listed, paddock tree cover represents greater than 44% of those communities remaining cover, and for six of these, paddock trees and clumps represent the only remaining vegetation component. This is supported by complementary work in NSW, where remote sensing methods showed that 54% of woodland dominated by Blakely's Red Gum *(E. blakelyi*), Yellow Box (*E. melliodora*) or White Box (*E. albens*) occurred in patches smaller than one hectare in size (Gibbons and Boak, in press). These former woodland communities continue to be selectively cleared, in the form of paddock tree removal.

The long-term conservation of some plant communities will need to incorporate the conservation of paddock trees, despite the lack of associated understorey. The occurrence of these communities across multiple landforms, drainage regimes, and soil types contribute to regional differences in biodiversity. In the short term, the conservation of these communities must incorporate strategies to conserve and replace paddock trees, or risk losing them completely. In particular, conservation of paddock trees across all pre-European plant communities, especially woodlands, will ensure sufficient potential for future restoration efforts.

The substantial differences between the mapping results for the South East and Tintinara study areas demonstrate the importance of understanding the landscape context of paddock trees as they occur in specific regions. In the Tintinara area the overall majority of tree canopies (diameter) is substantially smaller, i.e. 7m (64% of trees) compared with those in the South East, i.e. 10-20m. The remnancy figures for both areas are the same, however the total cover provided by paddock trees is substantially higher at Tintinara, and the complete clearance of some vegetation types has occurred. Ironically, clearance pressure in the Tintinara region is substantially less than in the South East region. However, overall dieback through higher susceptibility of Pink Gums to stress is of greater concern in this region. The differences between areas highlight the importance of choosing appropriately scaled mapping data, as management strategies and actions are often based on available data, and this may or may not be suitable.

The hand digitising method chosen to map paddock trees across both areas in South Australia has provided both accurate and detailed information previously not available. Mapping vegetation from aerial photography has considerable advantages over satellite-based data (Fensham and Fairfax, 2002). Manual digitising of individual trees has been shown to successfully avoid shadow effects (Hertwitz et al., 2000), while other studies have successfully been able to track the fate of individual trees by time-series aerial photography (Ozolins et al., 2001;Cameron et al., 2000;Sullivan and Venning, 1982). Some of the limitations include standardising image contrast and rectification, and the over-exaggeration of tree canopy cover to field cover, as photo scale declines (Fensham and Fairfax, 2002). While acknowledging the advantages of this mapping method, we recognise its constraints including the cost of imagery, the time and cost for staff to undertake the digitising, and the tedious nature of this mapping.

Satellite based mapping such as SPOT4 Panchromatic, a commonly used method for mapping paddock trees (Gibbons and Boak, in press;Department of Sustainability and Environment, 2003) has limitations as demonstrated by the comparison undertaken here. This includes the inability to discriminate between tree cover and 'other' vegetation cover such as low shrubs, inability to separate native from non-native and under representation of individual trees and small clumps of trees.

In comparing the digitising method with SPOT4 panchromatic imagery we found large differences between mapping results, such as 40% underestimate of trees in patches smaller than 0.06ha by SPOT4 mapping. We conclude that while the SPOT4 method may be a quicker and cheaper alternative method, it is has potential to be less reliable where paddock tree mapping is concerned. In particular we suspect that it will be unreliable in areas where tree canopies diameters are less than 10m, and where canopy dieback, and therefore thinning, is a problem, and in cases where accurate property level tree mapping is required.

6.1.1 Clearance

Analysis of authorised clearance information for the South East study area for the period 1997 to 2001 estimates the overall rate of loss over this four year period at 1.8%. In addition, loss from dieback has been estimated at a conservative 8% over a 33 year period for this region (Sullivan and Venning, 1982). If this loss is projected over the next 50 years, using current clearance and dieback rates, 36% of all existing paddock trees will be gone. An estimated 65% of this predicted loss will come from authorised clearance. This estimate assumes that the rate of loss from dieback will remain constant over time. As noted earlier, tree loss in itself causes further loss. The more likely prediction will be that rates of loss would be expected to increase over time, making this estimate, very conservative.

In addition to this the impact of authorised clearance on some species, in relation to the total remaining population, has been greater than others. For example, in the South East, a higher percentage of the total remaining Buloke and Pink Gum paddock trees are being cleared. As paddock trees become more isolated and as their health deteriorates, their value as habitat and as potentially long lived trees decreases, and approval for their clearance is more likely. Consequently those that remain become even more threatened from a conservation perspective.

6.1.2 Dieback

Our results suggest that minor levels of dieback are widespread across the study area, with 56% of trees surveyed suffering visible effects greater than 5%. This supports earlier work carried out in the region suggesting a dieback rate between 1945 and 1978 of 8 - 32% (Sullivan and Venning, 1982), and a later study estimating 81% of eucalypts surveyed contained some form of dieback (Paton and Eldridge, 1994). From our results, Pink Gum had the highest amounts of dieback, with 10% falling in the medium to high categories. It would be unlikely for these trees to recover if current causes of dieback are not removed. Causes of dieback are generally attributed to the detrimental impacts of farming practices. Dieback of paddock trees is a serious threat to their long term viability in the landscape. Dieback in remaining trees is further compounded by any loss that occurs around them, leading to greater exposure to climatic conditions (Cutten and Hodder, 2002). Seedling recruitment was only detected at one of the paddock trees sites, further supporting the evidence from across Australia, that loss of paddock trees through dieback is being compounded by lack of recruitment (Sullivan and Venning, 1982;Reid and Landsberg, 1999;Leahy, 2003) .

As Kile (1981) points out, in the absence of regeneration, the proportion of dead trees in any remnant population (including paddock trees) will continually increase as a consequence of natural or premature senescence. As trees age, their ability to tolerate or resist stress decreases, and many tree populations in many areas of Australia are probably of the order of 200-500 years old (Kile, 1981). Many trees in rural areas survive in spite of management, not because of it. And many landowners have a false sense of permanency concerning trees (Kile, 1981).

6.2 Bird Survey

6.2.1 Bird Species

Almost one third of all diurnal land birds previously recorded across the study area were recorded in paddock trees in this study. Most of the 47 species we recorded in paddock trees sites were also common to remnant sites. The most commonly observed birds recorded in paddock trees in our study included the open-country species Australian Magpie, honeyeaters including Red Wattlebird, White-plumed Honeyeater, Yellow-faced Honeyeater and Noisy Miner, parrots including Eastern Rosella, Musk Lorikeet, Crimson Rosella and Long-billed Corella and the small hollow-dependent insectivore Striated Pardalote. These results are comparable with other paddock tree surveys in NSW. 27 of the species recorded in paddock trees in our study were also recorded in a paddock tree study in NSW (Fischer and Lindenmayer, 2002a). The NSW study recorded 31 species using paddock trees (Fischer and Lindenmayer, 2002a) and a different NSW study recorded 35 diurnal bird species in isolated trees (Law et al., 2000). Parrots and granivores were commonly recorded at many sites, and this is similar to results found in other paddock tree surveys (Fischer and Lindenmayer, 2002a;Orr, 2003;Collard, 1999).

Many honeyeaters and small insectivorous birds, generally considered to be woodland dependent species, were recorded at our paddock trees sites, albeit in low numbers in comparison with those species commonly recorded. Other honeyeater species recorded included White-fronted Honeyeater, White-naped Honeyeater and New Holland Honeyeater. According to Major et al. (2001) the group of woodland species of greatest conservation concern tend to be small insectivores. The small insectivores that we recorded in paddock trees included the Silvereye, Spotted Pardalote, White-fronted Chat, Yellow-rumped Thornbill and Mistletoebird. In addition, some of the honeyeaters and small insectivorous birds we recorded are listed as declining in other areas of Southern Australia. They include Blue-faced Honeyeater, Brown-headed Honeyeater, White-plumed Honeyeater, Jacky Winter, Grey Fantail, Restless Flycatcher, Varied Sittella, and Yellow Thornbill (Paton, 1999;Fisher, 2000;Reid, 1999). Other larger declining bird species that we recorded using paddock trees included the Rufous Whistler, Musk Lorikeet and Red-rumped Parrot (Paton et al., 1999;Fisher, 2000). Major et al. (2001) in a study of woodland birds in the wheat belt of NSW found that the Grey Fantail and White-plumed Honeyeater showed a preference for large remnants greater than 200ha, however these were both recorded in paddock tree sites in our study.

An important finding from the bird observations in individual trees at sites is that after 2 visits, approximately 50% of trees had been visited by a bird and yet only 14% had birds recorded at both visits. This result is supported by another study (Orr, 2003) which found that after 10 visits to the same trees over a three month period, 93% of trees had recorded some bird use. These results indicate that many of the birds recorded were probably using paddock trees in a general habitat sense, rather than forming a specific dependency on an individual tree. This highlights the importance of all paddock trees for bird habitat.

Determining which species use paddock trees is important for assessing matrix tolerance of species and thus their vulnerability to habitat fragmentation (Law et al., 2000). Our results indicate that paddock trees across the landscape are being used by a substantial proportion of the region's birds and by many woodland birds normally associated with remnant patches. Most species using paddock trees were also using nearby remnants, indicating that these trees are probably part of these species' wider habitat. The presence of many bird species, listed as declining elsewhere, and recorded in paddock trees here, highlights the potential importance of all vegetation in maintaining the presence of these species in the landscape.

6.2.2 Bird Survey

The current SA point scoring system, which is used to assess the value of a paddock tree, in relation to whether its clearance should be permitted or not, is currently based largely on an individual tree's attributes. If the cover of a group of trees in an area also contributes to its ecological value in some way, then it is possible that the current point scoring system could be amended to take this site based factor into account. Our study therefore set out to test the relationships between the site (canopy) cover and bird density, species richness, and species diversity over 4ha paddock tree and remnant vegetation sites. Further to this, our study aimed to test whether the presence and/or abundance of particular species or groups of species were influenced by cover and vegetation type. Many tree, site and landscape parameters were measured for inclusion in our final analysis. The effect of landscape variables such as distance to nearest 20ha or 80ha native vegetation block, and the amount of native vegetation within a 1km, 2km and 5km radius were examined. The site variables of number of visible hollows present and the amount of timber on the ground were also investigated.

The results of the multiple linear regression modelling attempt to determine those explanatory variables that are statically important (significant). In a discussion of species richness studies, Gaston (1996) points out that the best models usually involve multiple environmental parameters, which may interact in a complex way. This is because often many factors may be causing the measured effect and only measuring one of these will not be enough. This is the case with the results of the study discussed here.

The low percentages of the R^2 coefficient for all of the statistically significant results presented here indicate that none of the models fit well and there is much unexplained variation in the response. This is to be expected when testing ecological data, where data collection can only account for on site responses being measured and many environmental factors that may be affecting results are unknown or unable to be measured. True replication of sites is in reality impossible as each site that is geographically different will have a unique set of environmental and landscape factors. Measuring an apparently simple variable of the effect of change in site cover on bird use in an area, becomes further complicated by the surrounding landscape.

In addition to this, the small sample size of the survey has probably contributed to the wide variation between individual site results. It is possible that were more sites included in the study, they may have had the effect of increasing the variation accounted for. Nevertheless, some factors have been shown to be significant by the modelling. These are discussed here as an indication of the kinds of relationships that are suspected of having an effect on the bird use of paddock tree sites as tested in the study, while acknowledging that many other environmental and landscape factors will affect these relationships.

The final model used for the step wise regression analyses included the variables of site cover, site hollows, site timber, distance to nearest 20ha remnant vegetation patch and the percent of native vegetation within 2km radius, number of trees, and the vegetation type. The three repeatedly significant variables determined from the modelling were site cover, vegetation type, and site timber.

6.2.3 Cover

Several Australian studies have attempted to estimate the relationship between remnant patch size and bird densities, species richness and composition. A study by Bennett (cited in Reid and Landsberg 1999) looking at bird densities, found that the number of birds per hectare was approximately 4 in open grassland, 11 in small stands of remnant trees, 17 in small (< 5ha) remnants and 12 in larger (30-200ha) remnants. Bird species richness in reserves in the WA wheatbelt was found to be related to reserve area (Kitchener et al., 1982). According to a study by Major et al. (2001), the composition of bird communities of sites with areas larger than 200ha were significantly different from that of sites less than 100ha. Often these relationships are measured in what is effectively remnant woodland habitat, and they appear well defined.

In our study, results of the comparison between the remnant and paddock tree sites, revealed there was a significant difference in species richness between remnant and paddock tree sites. As expected, remnant sites had significantly more species on average, compared to those in the paddock tree sites. Fischer and Lindenmayer (in press) found that remnant patches between 0.5ha and 1ha contained approximately one third of all bird species recorded in their study area. Our study found that paddock tree patches (from single trees to groups of trees up to 1ha) also contained one third of all bird species recorded for our study area. The similarity of these results indicates that relationships between remnant patch size and species richness may still operate in modified paddock tree habitat. The aim of our study was to examine the relationships of bird use normally measured in remnants, in paddock tree sites.

In a study looking at the effect of paddock tree clearance in the south east region of SA, tree removal was found to significantly modify bird communities (Collard, 1999). Transect counts showed large decreases in abundance and species richness of birds in areas where trees were cleared (Collard, 1999). This study equates an effective reduction in overall cover with a reduction in bird abundance and species richness. The reason this study was effective at recording this reduction was almost certainly because it represents a before and after snap shot of the same site. Our study was measuring the more general effect of post clearance cover where clearance occurred some time in the past. This poses the question of whether there is a more general rule that can be applied to relate overall bird use of paddock trees in an area with the amount of tree cover.

Orr (2003) looked at several vegetation density parameters including distance to nearest tree, the number of trees within 20m and whether the trees were touching. Results indicated that bird abundance and species richness increased with increasing isolation of the tree. This was also detected by Law et al. (2000) who suggested that when there were fewer trees to choose from any given tree was more likely to be occupied. Fischer and Lindenmayer (2002a) used a crown cover index based on the number of large and small crowns within a 100m radius of a site (a tree or a group of canopy touching trees). They concluded that there was an absence of cover effects as there was no significant relationship between site cover and the number of independently-acting groups of birds or species richness at a site.

Our study indicates that there is a relationship between site cover and bird density, species richness and species diversity but that this is related to other factors including timber on the ground and vegetation type. The results from the previous studies do not necessarily contradict this, however they highlight the problems of comparing bird use over different scales of measurement ie. 4ha site versus a single tree. Our study measured all bird activity in all trees for the cover effect being measured. Consequently, while cover around an individual tree may or may not seem to affect bird activity in that particular tree, at the overall site level its effect is evident. We found that there was a positive correlation between an increase in cover and an increase in bird density and species richness (where timber on the ground was low) and species diversity (where vegetation type had an effect). It is only possible to measure the effects of cover when all bird activity is measured in the area being assessed. It may still hold true that where there are fewer trees, the more likely a particular tree will be occupied. What our results suggest, however, is that where there is low timber present on the ground, as canopy cover increases, so does the bird density and species richness.

For species diversity, there was a positive relationship with site cover, but this was stronger at Blue/Pink Gum sites compared to Red Gum. Clearly these results indicate that changing tree cover does influence the density, richness and diversity of birds. The simplest explanation for this is that as tree cover increases, there is more available habitat, and the better the ‘quality’ of that habitat for birds in the locally surrounding area. From a conservation perspective, however, some birds are more important than others. In order to investigate whether cover was affecting the presence and abundance of different types of birds differently, different functional groups were also examined.

We defined group1 birds as birds requiring native woodlands and whose habitats extend into paddock trees. Species included in this group were Blue-faced Honeyeater, Grey Fantail, Jacky Winter, Laughing Kookaburra, Mistletoebird, and Rufous Whistler. This group showed no statistical correlation with cover at the paddock tree sites, due to low numbers recorded. However scatter plots visually revealed that when group 1 birds were present, the sites were more likely to be higher cover sites. There were also significantly more group 1 individuals in remnant sites than in the paddock tree sites. These birds were clearly showing a preference for cover that is closer to remnant vegetation cover, than paddock tree cover, while their presence at some of the higher cover paddock tree sites indicates they seem more likely to use paddock trees for habitat if the tree cover is high.

These group 1 species, with the exception of the Laughing Kookaburra and Mistletoebird, are listed as declining woodland birds elsewhere and many are small insectivores, highlighted as the group of woodland birds of most concern (Major et al., 2001). They are therefore a species of particular interest for conservation purposes given their preference for higher cover paddock tree and remnant sites. Tree thinning (i.e. clearance or dieback) of higher paddock tree cover areas (ie. > 6%), particularly in areas within 500m of 1ha or larger remnants, would therefore be expected to have a negative impact on these species, in areas where they occur. Two of the species in this group, the Laughing Kookaburra and Blue-faced Honeyeater require hollows for nesting, and would be likely to use paddock trees for this purpose in the breeding season. Removal of paddock trees with hollows may therefore have an impact on these species.

Group 2 birds were defined as those that live in eucalypts, even if the understorey is cleared, and are predominantly tree canopy feeders, including mobile nectar feeders. These included Striated Pardalote, Rosellas, Lorikeets, Cockatoos, and some of the more abundantly recorded honeyeaters such as White-naped, White-plumed, and Yellow-faced Honeyeaters, Red Wattlebird and Noisy Miner. Group 2 birds demonstrated an increase in abundance as cover increases, and indicated a preference for Blue/Pink Gum sites compared to Red Gum. This group of birds would be expected to suffer loss in numbers from habitat loss by thinning of paddock tree cover and removal or thinning of more intact vegetation. Many of the species in this group require hollows for nesting, and their presence in the region would be affected by the removal of hollow bearing trees.

Group 3 birds were defined as generalist species or open country feeding species, including Australian Magpie, Forest Raven, Long-billed Corella, Welcome Swallow and others. This group showed no relationship with site cover, and no difference in the number of individuals in remnant sites compared to paddock tree sites. This result indicates that tree cover is not a factor affecting the presence of these species, and suggests that they have no preference for either high or low cover sites. These species are therefore well described as generalist species. There were however more abundant at Red Gum sites than at Blue Gum/Pink Gum sites, indicating some preference for Red Gum. This lack of preference for sites with high or low cover was expected for this group, which contains the species of least concern for conservation purposes due to their adaptability to all types of habitat. Results suggest that management changes to either increase tree cover or alter its landscape configuration would have little effect on these species. The exception would be the hollow-nesting species in this group, who would be disadvantaged by the removal of hollow-bearing paddock trees from the landscape.

The results from our study indicate that relationships between cover and bird density, species richness and species diversity at paddock tree sites do exist. There was also an indication that the relationships differ for different groups of bird. These relationships however, are affected by other factors such as the presence of timber on the ground and vegetation type. The results demonstrate that simple cover and area relationships that hold true for more natural intact habitat, such as species composition or species diversity and remnant size, are not necessarily true for the heavily modified habitat represented by paddock trees. The results also indicate that each site is unique in relation to the birds it contains and their relative numbers.

It is likely that bird use of paddock tree habitat is related to many factors, probably specific to each species' particular requirements and to the suitability of the surrounding habitat. One of these factors is probably cover. From a management perspective, where paddock trees are assessed for either clearance or as potential recruitment sources, the existing cover around trees should be taken into account. The bird species of greater conservation value such as the group1 woodland dependent birds, along with many of the group 2 birds, along with the hollow nesters, bark-feeders and foliage-gleaners, all showed an increase in abundance as cover increased. As a general rule, our study indicates that paddock trees have greater biodiversity value for these regionally important bird populations if they are in greater densities, with cover as little as 6% (approximately 1.7 to 12.5 trees/ha) appearing to be important.

6.2.4 Vegetation Type

In a study by Major et al. (2001), vegetation type was the strongest determinant of bird communities in remnants. Collard (1999) also found differences in bird species' compositions at different paddock tree sites of differing vegetation type. Our results indicate that different vegetation types did have an affect on the abundance of individuals in different bird species groups. Group 1 species showed no preference between Blue/Pink or Red Gum sites. This group was the only one to demonstrate a preference for high cover paddock tree sites and remnant sites. This indicates that the overriding requirement for these species is cover and possibly site specific characteristics such as the quality of the nearest remnant, with actual vegetation type showing less importance. Group 2 and foliage-gleaners individuals were, on average, more abundant in Blue Gum/Pink Gum than Red Gum sites. The Blue Gum/Pink Gum sites and areas surrounding them had some trees flowering, and most trees were observed to contain lerps on their leaves. Neither of these factors were occurring at Red Gum sites. It is highly likely that this would make these Blue Gum/Pink Gum sites more attractive than those of Red Gums to the group 2 species, many of whom were observed feeding on both nectar and insects. Group3 individuals were, on average, more abundant in Red Gum sites than Blue/Pink Gum sites. This is possibly due to the greater variety of land uses in Red Gum areas that would provide additional food sources, for example irrigated pastures and vineyards, for these more generalist species.

Other responses investigated showed no relationship with vegetation type. This included Noisy Miner abundance, and species richness between remnant and paddock tree sites. The apparent preference for different groups of species for different vegetation types demonstrates the significance of all vegetation types in the conservation of bird species in general. The results of our study therefore support the suggestion that any plans for management of vegetation, including paddock trees, must consider vegetation type and not just vegetation cover (Major et al., 2001).

6.2.5 Timber

The presence of timber of the ground was a co-factor identified in the regression models for explaining bird density and species richness. A study of woodland birds in New England, NSW found that bird species richness, diversity, number of hollow nesters, number of foliage-gleaners and number of bark-feeders was positively correlated with fallen trees and branches (Ford and Barrett, 1995). Our study has been conducted in the more modified habitat of paddock trees and no such relationships were detected. The results from our study with regard to timber on the ground were inconclusive. The apparent relationships of timber on the ground with bird density or species richness can not be neatly separated from their association with cover or vegetation type.

A general observation from our results is that where there is low timber on the ground, the relationship of increasing cover with increasing bird density and species richness is clear. This may indicate that the effect of timber on the ground at some sites, adds to the habitat value of that site, meaning that less tree cover is needed for birds to use the site. It may be that timber on the ground adds to the habitat value of a paddock tree site, by providing additional food, resting and shelter resources or by creating the appearance of a more natural environment by providing more natural cover. Clearly the relationship to timber on the ground and bird species presence in paddock tree habitats is not a simple one and is related to many factors, many likely to be linked with the available habitat in the surrounding landscape. In the absence of clearer results we would maintain support for the suggestion that the tendency to remove dead timber for firewood or tidiness from paddock tree sites or remnants should be resisted (Ford and Barrett, 1995).

6.2.6 Distance

Several Australian studies have looked at the effect of distance to remnant on the distribution of particular type of bird guilds using paddock trees. Fischer and Lindenmayer (2002a) found that open country species such as Australian Magpie and Willie Wagtail were more likely to be detected at sites further than 200m from the nearest woodland patch, and nectarivores showed a trend to preferentially use sites further than 200m from the nearest woodland patch. Orr (2003) found that while all paddock trees up to 500m from a remnant were used by birds, abundance and species richness changed with distance. Other authors however have found that distance is not necessarily a limiting factor for bird use of paddock trees. The example of a Noisy Friarbird, in Eastwood state forest, NSW, detected in paddock trees 3 kms away from a nest it had completed is given by Ford and Barrett (1995). Honeyeaters regularly move distances of 10-100km in search of food within the Mt Lofty region (Paton et al., In Prep). Clearly there is a distinction between species that routinely move amongst habitats, such as honeyeaters, and those that are basically sedentary, such as treecreepers (Ford et al., 2001). As such the distance of paddock trees to the nearest remnant and their potential use by different birds, may only become important at the individual species level.

In the SA tree point scoring system, trees within 200m of a remnant are weighted more highly than trees further than 200m. Our study recorded a substantial number of birds and species using paddock trees up to 500m from remnants greater than 1ha. A recommendation from this study will be for the current SA tree scoring system to increase the distance, for trees receiving a weighting if they are within 200m of a remnant patch, to 500m, particularly if the paddock tree cover is 6% or greater.

As distance was a factor that was deliberately minimised in our study, we have no way of verifying whether distance from remnant patches is a key determinant for bird use of paddock trees. Studies exploring the effect of distance from remnants on bird use in paddock trees, may need to use much greater distances than the 500m we used to measure this effect. Our study demonstrated there was a relationship between site cover and bird density, species richness and species diversity, however this was found within a 100m – 500m distance from remnants. Orr (2003) raised the possibility of an ecotone effect in the 100-300m distance zone between remnants and the more true open country of paddock trees over pasture. It may be a possibility that this is an overall effect occurring in our study. In order to test this, replicas of our 4ha sites at distances of 1- 2km from remnants would be required.

6.2.7 Dieback

As well as investigating site relationships, individual tree characteristics such as dieback were also tested for significance with regard to bird use. Dieback has been found to be the most frequent significant negative predictor of the abundance or diversity of different groups of birds, with the exception of open country species. Paton and Eldridge (1994) found that the average number of birds per tree was higher for healthy trees, possibly a reflection of the higher canopy volume. Ford and Bell (1982) found fewer birds and fewer species of birds in woodlands suffering severe dieback than in healthy woodlands. Paton and Eldridge (1994) concluded that the numbers and diversity of birds using rural areas will decline even if all tree clearance stops, if loss of vigor in paddock trees continues.

6.2.8 Hollows

One of the most important components of paddock trees for wildlife are the hollows they contain for roosting and nesting, the availability of which, may be a limiting factor for some populations. They are used by an estimated 400 species of Australian vertebrates (Reid and Landsberg, 1999). A SA study of paddock trees found a fairly strong relationship between abundance of hollows of varying sizes and the presence of birds in paddock trees (Orr, 2003).

Our study found no relationships at the site level between bird density, species richness, species diversity or hollow nesting species and number of hollows at a site. This was probably due to the study being conducted outside of the breeding season for hollow nesters in the area. In addition to this the use of hollows is bird species and tree specific and not necessarily related to broader site factors, such as total number of hollows over an area. We recorded a total of 889 visible hollows in just 279 trees. Our results suggest that for all tree species surveyed, hollows are represented in a substantial proportion of paddock trees. In a study in Victoria, Bennett et al. (1994) found that most large trees on privately grazed land contained hollows, while patches on public land contained few hollow bearing trees. Red Gums are well recognised as hollow bearing trees, and our results indicated that 40% of trees contained at least one visible hollow. However 27% of Blue Gum and 20% of Pink Gums contained at least one visible hollow, indicating that these smaller trees also contribute substantially to the availability of hollows in the landscape.

The relationship between DBH (trunk diameter at breast height) and hollows in eucalypts has been well documented (Gibbons et al., 2000;Bennett et al., 1994;Lindenmayer et al., 2000). A study of hollow formation in four eucalypt species revealed that while living trees of all ages were observed to contain hollows, the proportions of trees with hollows increased with tree age (Gibbons et al., 2000). Bennett et al., (1994) found that both stem diameter and tree species were significant predictors of the total number of holes in a tree. Trees score highly in the SA clearance assessment process if they contain hollows. Our results however indicate that for trees with a DBH as low as 20cm in Pink Gum, 50cm in Blue Gum and 60cm in Red Gum, all contained a visible hollow. As these trunk diameters would be considered quite small, and these trees relatively young, it is important to recognise that younger or smaller trees are important for their potential to produce hollows at some point in the future. As Bennett et al., (1994) point out, the availability of hollows for wildlife over the next century will be largely influenced by the capacity of tree regeneration and growth throughout farmland areas. Assessment criteria for tree clearance should therefore take potential hollow development into consideration. This is currently not taken into consideration in the SA tree point scoring system. Another conservation issue directly related to tree dieback and lack of recruitment is the future availability of hollows in the landscape.

6.2.9 Aggressive Birds – Noisy Miner

Several studies have linked the presence and aggressive behaviour of Noisy Miners to the exclusion of other bird species in remnants, in particular honeyeaters (Grey et al., 1997;Grey et al., 1998) and small insectivorous birds (Major et al., 2001). Commonly, Noisy Miners are associated with having an adverse effect on bird species distributions, in particular where small remnants are concerned i.e. 5-20ha (Major et al., 2001;Ford and Barrett, 1995). In particular the absence of understorey is associated with Noisy Miner success in fragmented habitat (Grey et al., 1998). Ford et al. (2001) describe the presence or absence of Noisy Miners as one of the most significant factors determining the abundance and diversity of birds in remnant vegetation in south-eastern Australia.

Noisy Miners were present in approximately 40% of the paddock trees study sites and 61% of the remnant sites. Results indicated that the presence of Noisy Miners do not have an effect on either the presence of honeyeaters or small birds in either the paddock tree or remnant sites. Our results also suggest that there is no relationship between the presence of Noisy Miners and site cover or vegetation type, but species diversity was on average higher in paddock tree sites with Noisy Miners compared to sites without Noisy Miners.

One explanation for the non-exclusionary behavior of Noisy Miners at these sites may be that the survey was conducted during the non-breeding season for Noisy Miners (autumn), when they are unlikely to be defending nesting territory. Our survey would need to be repeated in spring for this to be tested. Another explanation may be that there were few trees flowering at the time of the survey and the bulk of honeyeaters and small birds were feeding on insects on tree leaves. It may be that competition between these groups and Noisy Miners was therefore less than would be expected for nectar resources. The resultant higher average diversity at Noisy Miner sites compared with non Noisy Miner sites could therefore simply be reflecting the reality that Noisy Miners tend to use sites favored by other species, and that in this region their presence reflects a site with higher diversity.

It is also possible that Noisy Miners do not have a detrimental effect on the bird species we recorded in the vegetation types that were investigated. In another study in the south east region of SA, Noisy Miners were found to be associated with, and have a detrimental effect on bird species diversity and abundance at paddock tree sites containing Rough-barked Manna Gum (*E. viminalis ssp.*

cygnetensis), but not at sites containing Pink Gums (Collard, 1999). Similarly, Major et al (2001) found that the relationship between bird community composition of remnants in which Noisy Miners were present, compared with those in which they were absent, was not significantly different for all vegetation types (Major et al., 2001).

6.2.10 Landscape

Paddock trees are used by many species and they probably influence the connectivity of forest remnants, particularly as stepping stones (Law et al., 2000). Fischer and Lindenmayer (2002b) also concluded that paddock trees have the potential to enhance landscape connectivity by acting as stepping stones to assist movement. They found that all groups of birds examined tended to return to their place of origin or move in the opposite direction of their arrival. Orr (2003) also concluded that birds used paddock trees not only to move across the landscape, but to travel between larger patches. This study concluded that woodland patches appeared to act as centres of bird activity in the landscape (Orr, 2003) with paddock trees the 'spokes'.

While our study has demonstrated that paddock tree cover over an area and bird use are sometimes related, we were unable to determine if there were any broader landscape relationships. While we measured landscape variables such as distance to vegetation remnants of various sizes, and calculated amounts of vegetation cover within set distances of each site, none of these were found to be significant in the regression modelling approach that was used. The reason for this is most likely that the variation in these landscape parameters was so great between sites that no pattern was likely to be detected. For example in Red Gum paddock tree sites, distances to a 20ha or larger remnants ranged from 100m to 4,817m, and native vegetation cover within a 2km radius varied between 2.8% and 24.7%. For these types of broader landscape parameters to be tested, replicate sites would need to have been chosen to specifically test these variables.

The difficulty of testing the effect of landscape parameters is also related to the scale. A study by Major et al., (2001) found that remnant attributes appeared to be more important than landscape attributes in determining the composition of bird communities. However a study in Victoria of woodland birds by Bennett and Ford (1997), found that species richness was best predicted by total tree cover along with measures of environmental variation. The study suggested that at least 10% tree cover would be needed to prevent serious declines in woodland avifauna. The Mount Lofty Ranges of SA is one region where vegetation cover has fallen bellow 10% and a decline in large numbers of woodland birds is now being recorded (Paton et al., 1999). While our south east study area had an overall vegetation cover of less than 10% around individual paddock tree sites, cover varied from 2.9% to 15.6% within a 5km radius. One probable conclusion from these studies is that the overall effect of vegetation cover at a scale that is regional (over 10 to 100's of km), as suggested by Bennett and Ford (1997) and Paton et al., (1999) will have an effect on overall population decline of woodland birds. In combination with this, species' specific losses in local areas, will possibly relate more to the local availability of suitable habitat and the overall quality of the agricultural matrix for birds.

It may be more realistic to view the landscape as variegated, consisting of a mosaic of patches of differing quality (McIntyre and Barrett, 1992). Many species of birds see natural habitats as consisting of patches that vary greatly in quality and even in a highly fragmented and degraded habitat, birds can use a wide range of sites other than those of the best quality (Ford and Barrett, 1995). Fahrig (2001) suggests that while reproductive rate has the largest potential effect on the extinction threshold for fauna populations, matrix quality was more important than fragmentation. Habitat patches are parts of the landscape mosaic and the presence of a species in a patch may be a function not only of patch size and isolation, but also of the neighbouring habitat (Andrén, 1994). Conservation strategies therefore should consider the quality of the whole landscape including the matrix (Fahrig, 2001). We therefore consider the role of paddock trees for bird conservation is important.

7 MURRAY-DARLING BASIN AND NATURAL RESOURCE MANAGEMENT VEGETATION COVER TARGETS

One of the most obvious implications of a lack of information regarding the use by paddock trees by fauna and an associated lack of mapped information about their distribution and cover is that they are not readily or easily incorporated into policy targets. A conceptual framework for developing and implementing terrestrial biodiversity targets within the Murray-Darling Basin has been developed (James and Saunders, 2001). Because fauna at all taxonomic levels generally rely on habitat created by plants, the vegetation type and extent are used to reflect different possible combinations of a range of species. In this way, vegetation type and extent are used as surrogate measures of terrestrial biodiversity. Results from our bird study support this assumption, with results indicating that different bird species show preference for particular vegetation types over others. Guidelines for targets are based on current understanding, with a minimum acceptable goal set at 30% native vegetation cover, and a recommended landscape level of native vegetation cover lying between 30% and 70%. A similar framework, to assist regions in the process of target setting to maintain biodiversity, is currently under development as part of a National Framework for Natural Resource Management (NRM) (Natural Resource Management Ministerial Council, 2002).

Paddock trees are not reflected in these targets predominantly because, for the most part, they are not mapped and do not contribute to biodiversity in the same way that remnant patches do. In areas of the Australia where paddock trees are a landscape feature, such as the study areas examined in our project, a cover target may need to be determined separately for the paddock tree component. These would need to be determined at a property scale, rather than being based on the area occupied by individual tree canopies alone, and would need to take into account a likely higher mortality rate for paddock trees. As the majority of paddock trees represent the remnants of vegetation types that for the most part no longer remain in the larger intact patches, their conservation will need to be ensured if the vegetation cover that remains is to adequately represent a sample of what existed prior to clearance. In addition to this, particular important features of paddock trees, such as hollows (both existing and future), may not be represented in the extant vegetation found in larger patches in the landscape.

Quantitative assessment indicates that cover by paddock trees, at the level of vegetation type, whether isolated or in small patches, should be considered as an additional category when determining regional vegetation targets within the MDB, and other regions where paddock tree woodland communities remain. Without this, vegetation cover targets will overlook large amounts of vegetation cover and plant communities in the landscape, and management strategies will continue to undervalue the role of paddock trees in biodiversity conservation.

8 SUMMARY

Paddock trees are not substitutes for intact remnant vegetation, and it is not the intention of this study to suggest otherwise. They are however an important component of remnant vegetation that provides a particular source of habitat and resources to many invertebrate and vertebrate species. In many cases they represent the last structural component of particular plant communities otherwise cleared from the landscape and they have a conservation value in this respect alone. Theory and research indicate that the net result of paddock tree loss, is the loss of biodiversity and habitat, further fragmentation of the ecological system (Cutten and Hodder, 2002), and the continuation of the extinction debt, (the future loss of species that is a consequence of past actions (Possingham, 2000)).

From studies to date, it is clear that the majority of paddock trees will not survive much past the next century under current management regimes. For management to change there needs to be a clearer understanding and recognition of the value of paddock trees for their social and amenity value, their farm production and economic value, and their ecological and habitat value. Management of the paddock tree resource clearly needs to relate to reducing the underlying impacts of farming practices that currently affect tree health, longevity and recruitment, and better integration of tree management with overall farm management.

Both a landscape and farm level approach for management is required. The landscape level will need to assess broad habitat requirements of species likely to use them and any requirements for connectivity between larger remnants. A farm level approach will need to ensure that trees in paddocks are protected in appropriate ways from the impacts of stock and cropping. Paddock tree recruitment will also need to be addressed at both levels if trees are to persist into the future. The tree re-generation gap is a problem described by Robinson (1995p.14),

"*If we simply ignore the constant deaths of older trees and pretend that our young, planted trees offer substitute habitat, then most animals and plants dependent on those old trees will be well and truly locally extinct by the time those young trees have grown up*."

One of the most important findings of our study is that paddock trees represent an important and unrecognised component of vegetation cover in both regions, which should not be left unaccounted for in landscape conservation planning. We suggest that cover by paddock trees and small patches should be considered as an additional category when determining regional vegetation targets in regions where paddock tree woodland vegetation types remain.

This study indicates that paddock tree cover is a significant factor influencing bird use of paddock trees. Vegetation type also plays a significant role in influencing the abundance of particular species. The results also indicate that each site is unique in relation to the birds it contains and their relative numbers. Bird use of paddock tree habitats is therefore determined by many factors, probably specific to each species' particular requirements and to the suitability of the surrounding habitat.

According to Law et al., (2000) conservation efforts focussing only on forest reserves or remnants, while ignoring the matrix, will often have limited success. The presence of birds in a particular remnant (or paddock tree) does not mean that the sub-population it belongs to is viable, or that it is making a beneficial contribution to the metapopulation (Major et al., 2001). In the case of paddock trees however, it does indicate that a particular tree is being used and is therefore contributing in some way to the habitat value of that environment. In our study area, paddock trees undoubtedly contribute to the quality of the matrix for birds, and to the habitat value of the region as a whole.

Clearance together with dieback estimates, place the conservative loss of paddock trees in the South East study area to be 36% over the next 50 years, with 65% of this predicted loss attributed to clearance. In addition to this, tree recruitment was only recorded at one of the paddock tree sites surveyed. This highlights the need for a clear regional strategy for the conservation of paddock trees, as well as investigation and discussion into the contribution of paddock trees to biodiversity conservation and ecological communities as a whole. An expansion of the current tree evaluation system (Cutten and Hodder, 2002) to include a tree's value at the local landscape scale, may result in greater restrictions for clearance of some trees. Similarly, results indicating the significance of cover and vegetation type could be used to provide guidelines for more strategic management and recruitment of paddock trees for long term conservation. Results could also be used to assist in further developing guidelines for placement and design of revegetation areas in paddock tree areas.

9 REFERENCES

ACT Parliamentary Council (2002) *Nature Conservation Act 1980*, ACT Parliamentary Council. http://www.legislation.act.gov.au/a/1980-20/current/pdf/1980-20.pdf

Andrén, H. (1994) Effects of habitat fragmentation on birds and mammals in landscapes with different proportions of suitable habitat: a review, *Oikos,* **71,** 355-366.

Bell, H. L. and Ferrier, S. (1985) The Reliability of Estimates of Density from Transect Counts, *Corella,* **9,** 3-13.

Bennett, A. and Wilson, J. (1999) *A patchy resource... Wildlife and nectar*, State of Victoria, Department of Natural Resources and Environment. [http://www.dse.vic.gov.au/web/root/domino/cm_da/nreninf.nsf/frameset/NRE+Information+Series?OpenDocument&[/4A2568B2008332A3/BCVIEW/B305BB10F5FB520BCA256C39001B4838?OPENDOCUMENT]

Bennett, A. F. (1990) Habitat corridors and the conservation of small mammals in a fragmented landscape, *Landscape Ecology,* **4,** 109-122.

Bennett, A. F. and Ford, L. A. (1997) Land use, habitat change and the conservation of birds in fragmented rural environments: a landscape perspective from the Northern Plains, Victoria, Australia, *Pacific Conservation Biology,* **3,** 244-61.

Bennett, A. F., Lumsden, L. F. and Nicholls, A. C. (1994) Tree hollows as a resource for wildlife in remnant woodlands: spatial and temporal patterns across the northern plains of Victoria, Australia, *Pacific Conservation Biology,* **1,** 222-235.

Bickerton, H. (2001) *Mapping scattered trees in the South East of South Australia: a pilot project*, Native Vegetation Council, Department for Environment and Heritage.

Bickerton, H., Carruthers, S., Brook, A. and Hodder, M. (2002) *A Landscape Approach to Determine the Ecological Value of Scattered Trees. Summary Report Year 1.*, Biodiversity Assessment Services, SA Department of Water, Land and Biodiversity Conservation.

Bird, P. R., Bicknell, D., Bulman, P. A., Burke, S. J. A., Leys, J. F., Parker, J. N., Sommen, F. J. v. d. and Voller, P. (1992) The role of shelter in Australia for protecting soils, plants and livestock, *Agroforestry Systems,* **20,** 59-86.

Bird, R. (1990) Sheltering the farm - an economic assessment of trees, *Rural Quarterly.* **1** 12-13

Brower, J. E., Jerrold, H. Z. and von Ende, C. N. (1989), *Field and Laboratory Methods for General Ecology,* Win C Brown Publishers.

Cale, P. G. and Hobbs, R. J. (1994) Landscape heterogeneity indices: problems of scale and applicability, with particular reference to animal habitat description, *Pacific Conservation Biology,* **1,** 183-193.

Cameron, A. D., Miller, D. R., Ramsay, F., Nikolaou, I. and C., C. G. (2000) Temporal measurement of the loss of native pinewood in Scotland through the analysis of orthorectified aerial photographs, *Journal of Environmental Management,* **58,** 33-43.

Celebrezze, T., Hill, B., Mercer, K. and Paton, D. C. (1996) *Overview of the annotated bibliography on the value of isolated native trees*, Department of Environment and Natural Resources, South Australia.

Chilcott, C., Reid, N. C. H. and King, K. (1997) Impact of trees on the diversity of pasture species and soil biota in grazed landscapes on the Northern Tablelands, NSW In *Conservation Outside Nature Reserves*(Eds, Hale, P. and Lamb, D.) University of Queensland, Brisbane, pp. 378-386.

Collard, S. (1999) *Initial changes to woodland bird communities in response to the clearance of scattered eucalypt trees,* Department of Environmental Biology University of Adelaide

Collard, S. (2000) Initial changes to woodland bird communities in response to the clearance of scattered eucalypt trees, *Australian Biologist,* **13**.

Croft, T. (1999) NPWSA, Department for Environment and Heritage and Information and Data Analysis Branch, Planning, Department of Transport Urban Development and the Arts., Adelaide.

Croft, T. (In prep) *Pre-European Floristic Vegetation Mapping of South Australia: Murray Mallee Region*, South Australian Department for Environment and Heritage.

Croft, T. and Carpenter, G. (Unpublished) *The Biological Resources of the South East - DRAFT. Unpublished Report.*, Biological Survey and Monitoring, Department for Environment and Heritage.

Croft, T. S., Carruthers, S., Possingham, H. and Inns, R. (1999) *Biodiversity Plan for the South East of South Australia*, Department for Environment, Heritage, and Aboriginal Affairs, South Australia.

Croft, T. S. and Venning, J. (1983) *The extent and severity of tree decline in agricultural regions of South Australia*, Conservation Programmes Division, Department of Environment and Planning.

Cutten, J. L. and Hodder, M. W. (2002) *Scattered Tree Clearance Assessment in South Australia: Streamlining, Guidelines for Assessment, and Rural Industry Extension*, Biodiversity Assessments Section, Department for Environment and Heritage, South Australia.

Department of Infrastructure (2001) *Schedule 2 to the Environmental Significance Overlay. West Wimmera Planning Scheme. Planning Schemes.*, Department of Infrastructure, Government of Victoria. http://www.doi.vic.gov.au/DOI/PSO/westwimmer a.nsf/ByDominoFilename/westwimmera_ordinance_42_01s02_wwim.pdf/$FILE/42_01s02_wwim.pd

Department of Natural Resources and Environment, V. (1999) *Vicmap: Tree Cover Density Mapping*, Department of Natural Resources and Environment, Victoria,.

Department of Sustainability and Environment (2003) *Tree Cover, Statewide 1:25,000 Tree Cover Mapping Program. First Published June 2000.*, Produced by The Land Information Group, Land Victoria, Department of Sustainability and Environment.

Diamond, J. M. (1975) The island dilemma: lessons of modern biogeographic studies for the design of natural reserves, *Biological Conservation,* **7,** 129-146.

DWLBC (2003) Native Vegetation Database (Heritage Agreement and vegetation clearance applications), South Australian Department for Water Land and Biodiveristy Conservation (DWLBC) / Department for Environment and Heritage (DEH) June 2003.

Fahrig, L. (2001) How much habitat is enough?, *Biological Conservation,* **100,** 65-74.

Fahrig, L. and Merriam, G. (1994) Conservation of fragmented populations, *Conservation Biology,* **8,** 50-59.

Fensham, R. J. and Fairfax, R. J. (2002) Aerial photography for assessing vegetation change: a review of applications and the relevance of findings for Australian vegetation history, *Australian Journal of Botany,* **50,** 415-429.

Fischer, J. and Lindenmayer, D. B. (2002a) The conservation value of paddock trees for birds in a variegated landscape in southern New South Wales 1. Species composition and site occupancy patterns, *Biodiversity and Conservation,* **11,** 807-832.

Fischer, J. and Lindenmayer, D. B. (2002b) The conservation value of paddock trees for birds in a variegated landscape in southern New South Wales 2. Paddock trees as stepping stones, *Biodiversity and Conservation,* **11,** 833-849.

Fischer, J. and Lindenmayer, D. B. (in press) Small patches can be valuable for biodiversity conservation: two case studies on birds in southeastern Australia, *Biological Conservation*.

Fisher, A. M. (2000) On the future for birds in a multi-use landscape In *Nature Conservation 5: Nature Conservation in Production Environments: Managing the Matrix*(Eds, Craig, J. l., Mitchell, H. and Saunders, D. A.) Surrey Beatty & Sons, pp. 623-32.

Ford, H. A. and Barrett, G. (1995) The role of birds and their conservation in agricultural systems In *People and Nature Conservation: perspectives on private land use and endangered species*(Eds, Bennett, A. F., Backhouse, G. and Clark, T.) Transactions of the Royal Society of New South Wales, Sydney, pp. 128-134.

Ford, H. A., Barrett, G. E. and Recher, H. F. (1995) Birds in a degraded landscape - safety nets for capturing regional biodiversity In *Nature Conservation 4: The Role of Networks*(Eds, Saunders, D. A., Craig, J. l. and Mattiske, E. M.) Surrey Beatty & Sons, pp. 43-50.

Ford, H. A., Barrett, G. W., Saunders, D. A. and Recher, H. F. (2001) Why have birds in the woodlands of Southern Australia declined?, *Biological Conservation,* **97,** 71-88.

Ford, H. A. and Bell, H. F. (1982) Density of birds in eucalypt woodland affected to varying degrees by dieback, *Emu,* **82,** 202-208.

Gaston, K. J. (1996) Species richness: measure and measurement In *Biodiversity, a biology of numbers and differences*(Ed, Gaston, K. J.) Blackwell Science, Cambridge, MA, pp. 77-113.

Gibbons, P. and Boak, M. (in press) The value of paddock trees for regional conservation in an agricultural landscape, *Ecological Management and Restoration*.

Gibbons, P., Lindenmayer, D. B., Barry, S. C. and Tanton, M. T. (2000) Hollow formation in eucalypts from temperate forests in southeastern Australia, **6,** 218-228.

Government of South Australia (2000) *Sustainable development in South East South Australia: prototype information system*, Natural Resources Council.

Government of South Australia (2003) *Native Vegetation Act 1991 (Reprint No. 4)*, http://www.parliament.sa.gov.au/dbsearch/regs-list.htm

Government of Western Australia (2002) *Environmental Protection (Land Clearance) Amendment Bill 2002, Western Australia.*, http://www.parliament.wa.gov.au/parliament/bills.nsf/FC8F42CDDC2F81BF48256BE5001F42A6/$File/Bill131-1.pdf

Grey, M. J., Clarke, M. F. and Loyn, R. H. (1997) Initial changes in the avian communities of remnant eucalypt woodlands following a reduction in the abundance of noisy miners, *Manorina melanocephala*, *Wildlife Research,* **24,** 631-648.

Grey, M. J., Clarke, M. F. and Loyn, R. H. (1998) Influence of the Noisy Miner *Manorina melanocephala* on avian diversity and abundance in remnant Grey Box woodland, *Pacific Conservation Biology,* **4,** 55-69.

Griffin, A. R. and Cotterill, P. P. (1987) Genetic Variation in Growth of Outcrossed, Selfed and Open-Pollinated Progenies of *Eucalyptus regnans* and some Implications for Breeding Strategy, *Silvae Genetica,* **37,** 124-131.

Guevara, S., Laborde, J. and Sánchez, G. (1998) Are isolated remnant trees in pastures a fragmented canopy?, *Selbyana,* **19,** 34-43.

Haila, Y., Saunders, D. A. and Hobbs, R. J. (1993) What do we presently understand about ecosytem fragmentation? In *The Reconstruction of Fragmented Ecosytems*(Eds, Saunders, D. A., Hobbs, R. J. and Ehrlich, P. R.) Surrey Beaty and Sons Pty Ltd, pp. 45-55.

Hall, F. (2003) Out on a limb: the meaning of isolation for remnants, *Thinking Bush.* **2** 6-8

Hardner, C. M. and Potts, B. M. (1994) Inbreeding Depression and Changes in Variation After Selfing in *Eucalyptus globulus* ssp. *globulus*, *Silvae Genetica,* **44,** 47-54.

Harris, W. (1999) *Revegetation: its biodiversity conservation effectiveness,* Department of Environmental Biology University of Adelaide

Heard, L. M. B. and Channon, B. (1997), *Guide to a Native Vegetaion Survey (Agricultural Region) Using the Biological Survey of South Australia Methodology,* Geographic Analysis and Research Unit, Information and Data Analysis Branch, Department of Housing and Urban Development, Adelaide.

Heard, L. M. B. and Goodwins, D. R. (1999) Information and Data Analysis Branch, Planning SA, Adelaide.

Hertwitz, S. R., Sandler, B. and Slye, R. E. (2000) Twenty-one years of crown change in the Jasper Ridge Biological Preserve on georeferenced multitemporal aerial photographs., *International Journal of Remote Sensing,* **21,** 45-60.

Hill, B. M., Laan, T. and Paton, D. C. (1997) *Use of isolated trees by native fauna in the Mount Lofty Ranges*, Department of Zoology, University of Adelaide.

James, C. and Saunders, D. A. (2001) *A Framework for Terrestrial Biodiversity Targets in the Murray-Darling Basin (Draft)*, CSIRO Sustainable Ecosystems and Murray-Darling Basin Commission.

Johnson, H. (2002) *Landcare Notes, Native Vegetation Retention Controls*, Department of Natural Resources and Environment, State Government of Victoria. http://www.nre.vic.gov.au/web/root/domino/cm_da/nreninf.nsf/frameset/NRE+Information+Series?OpenDocument

Kahrimanis, M. J., Carruthers, S., Opperman, A. and Inns, R. (2001) *Biodiversity Plan for the South Australian Murray-Darling Basin*, Department for Environment and Heritage, South Australia.

Kile, G. A. (1981) An overview of eucalypt dieback in rural Australia In *Eucalypt Dieback in Forests and Woodlands*(Eds, Old, K. M., Kile, G. A. and Ohmart, C. P.) CSIRO, Melbourne, pp. 13-26.

Kinnear, S. and Gillen, J. (1999) Information and Data Analysis Branch, Planning SA, Department of Transport Urban Planning and the Arts, Adelaide.

Kitchener, D. J., Dell, J. and Muir, B. G. (1982) Birds in Western Australian wheatbelt reserves - implications for conservation, *Biological Conservation,* **22,** 127-163.

Land and Water Conservation (1998) *Offsets, Salinity and Native Vegetation Discussion Paper*, NSW Department for Land Water and Conservation,. http://www.dlwc.nsw.gov.au/care/salinity/offsets.html

Land and Water Conservation (1999a) *Clearing Scattered Paddock Trees for Spray Irrigation Systems - Guidelines for Applicants*, NSW Department of Land and Water Conservation. http://www.dlwc.nsw.gov.au/care/veg/pdfs/pivotapl.pdf

Land and Water Conservation (1999b) *Clearing Scattered Paddock Trees for Pine Plantations in the Murray and Murrumbidgee Regions - Guidelines for Applicants.*, NSW Department for Land and Water Conservation. http://www.dlwc.nsw.gov.au/care/veg/pdfs/pineapl.pdf

Law, B. S. and Anderson, J. (2000) Roost preferences and foraging ranges of the eastern forest bat *Vespadelus pumilus* under two disturbance histories in northern NSW, Australia, *Austral Ecology,* **25,** 352-367.

Law, B. S., Anderson, J. and Chidel, M. (1999) Bat communities in a fragmented forest landscape on the south-west slopes of New South Wales, Australia, *Biological Conservation,* **88,** 333-345.

Law, B. S., Chidel, M. and Turner, G. (2000) The use by wildlife of paddock trees in farmland, *Pacific Conservation Biology,* **6,** 130-143.

Law, B. S. and Dickman, C. R. (1998) The use of habitat mosaics by terrestrial vertebrate fauna: implications for conservation and management, *Biodiversity and Conservation,* **7,** 323-333.

Leahy, J. (2003) *Tree Decline: A North East Perspective*, Department of Primary Industries, Victoria.

Lindenmayer, D. B., Cunningham, R. B., Pope, M. L., Gibbons, P. and Donnelly, C. F. (2000) Cavity sizes and types in Australian eucalypts from wet and dry forest types - a simple of rule of thumb for estimating size and number of cavities, *Forest Ecology and Management,* **137,** 139-150.

Lorimer, M. (2003) *A Landscape Approach to Determine the Ecological Value of Scattered Trees - Project Report - Statistical Analysis of Site Data*, BiometricsSA.

Loyn, R. (1986) The 20 minute search: a simple method for counting forest birds, *Corella,* **10,** 58-60.

Loyn, R. H. and Middleton, W. G. D. (1981) Eucalypt Decline and Wildlife In Rural Areas In *Eucalpyt Dieback in Forests and Woodlands*(Eds, Old, K. M., Kile, G. A. and Ohmart, C. P.) CSIRO, Melbourne, pp. p95-111.

Lumsden, L., Bennett, A., Silins, J. and Krasna, S. (1994) *Fauna in a remnant vegetation-farmland mosaic: movements, roosts and foraging ecology of bats*, Flora and Fauna Branch, Department of Conservation and Natural Resources, Victoria.

Lumsden, L. F., Bennett, A. F., Krasna, S. and Silins, J. (1995) The conservation of insectivorous bats in rural landscapes of northern Victoria In *People and Nature Conservation: perspectives on private land use and endangered species.*(Eds, Bennett, A. F., Backhouse, G. and Clark, T.) Transactions of the Royal Society of New South Wales, Sydney.

Majer, J. and Recher, H. (2000) A tree alone, *Nature Australia***,** 58-65.

Majer, J. D., Recher, H. F. and Keals, N. (2000) Canopy arthropod faunas in fragmented agricultural landscapes In *Temperate Eucalypt Woodlands in Australia*(Eds, Hobbs, R. J. and Yates, C. J.) Surrey Beatty and Sons, Chipping Norton, pp. 235-247.

Major, R. E., Christie, F. J. and Gowing, G. (2001) Influence of remnant and landscape attributes on Australian woodland bird communities, *Biological Conservation,* **102,** 47-66.

McIntyre, S. and Barrett, G. E. (1992) Habitat variegation, an alternative to fragmentation, *Conservation Biology,* **6,** 146-147.

McIntyre, S. and Hobbs, R. J. (1999) A framework for conceptualizing human effects on landscapes and Its relevance to management and research models, *Conservation Biology,* **13,** 1282-1292.

National Land and Water Resources Audit (2001), *Australian Native Vegetation Assessment 2001,* Commonwealth of Australia, Canberra.

Natural Resource Management Ministerial Council (2002) *Biodiversity Conservation Outcomes and Targets for Natural Resource Management*, Standards and Targets Working Group, Natural Heritage Trust and Biodiversity Policy Branch, Environment Australia.

Natural Resources and Environment (2002a) *Victoria's Native Vegetation Management. A4 Brochure*, Victorian Department for Natural Resources and Environment, Government of Victoria. http://www.nre.vic.gov.au/web/root/domino/cm_da/nrenlwm.nsf/frameset/NRE+Land+and+Water?OpenDocument&[/4A25676D0024CB20/BCView/3BA0EB9CB247BB1FCA256C230023A884?OpenDocument]

Natural Resources and Environment (2002b) *Victoria's Native Vegetation Management. A Framework for Action*, Department for Natural Resources and Environment, Government of Victoria. http://www.nre.vic.gov.au/web/root/domino/cm_da/nrenlwm.nsf/frameset/NRE+Land+and+Water?OpenDocument&[/4A25676D0024CB20/BCView/3BA0EB9CB247BB1FCA256C230023A884?OpenDocument]

Orr, K.-J. (2003) *Assessing the ecological value of scattered trees for birds in an agricultural landscape in South East South Australia,* Department of Environmental Biology University of Adelaide

Ozolins, A., Brack, C. and Freudenberger, D. (2001) Abundance and decline of isolated trees in the agricultural landscapes of Central New South Wales, Australia., *Pacific Conservation Biology,* **7,** 195-203.

Paton, D. C. (1999) Managing Bird Populations, *Environment SA.* **7** 22-23

Paton, D. C., Carpenter, G. and Sinclair, R. G. (1994) A Second Bird Atlas of the Adelaide Region. Part 1: Changes in the Distribution of Birds: 1974-75 vs 1984-85, *South Australian Ornithologist,* **31**.

Paton, D. C. and Cutten, J. L. (2000) Mundulla yellows: a growing concern, *Danthonia,* **8,** 1-5.

Paton, D. C. and Eldridge, S. (1994) *Maintenance of mature trees in agricultural areas in the Upper South East of South Australia*, Department of Zoology, University of Adelaide.

Paton, D. C., Prescott, A. M., Davies, R. J.-P. and Heard, L. M. (1999) The distribution, status and threats to temperate woodlands in South Australia In *Temperate Eucalypt Woodlands in Australia*(Eds, Hobbs, R. J. and Yates, C. J.) Surrey Beatty and Sons, Chipping Norton, pp. 57-85.

Paton, D. C., Rogers, D. J. and Harris, W. (2003) Birdscaping the environment: restoring the woodland systems of the Mt Lofty region, South Australia In *Conservation of Australia's Forest Fauna*.

Paton, D. C., Rogers, D. J. and Harris, W. (In Prep) Birdscaping the environment: restoring the woodland systems of the Mt Lofty region, South Australia In *Conservation of Australia's Forest Fauna*.

Possingham, H. P. (2000) The Extinction Debt: The future of birds in the Mount Lofty Ranges, *Environment SA.* **8** 10

Prober, S. and Brown, A. H. D. (1994) Conservation of the grassy White Box woodlands: population genetics and fragmentation of *Eucalyptus albens*, *Conservation Biology,* **8,** 1003-1013.

Recher, H. F. (1999) The state of Australia's avifauna: a personal opinion and prediction for the new millennium, *Australian Journal of Zoology,* **31,** 11-27.

Recher, H. F., Holmes, R. T., Schulz, M., Shields, J. and Kavanaugh, R. P. (1985) Foraging patterns of breeding birds in eucalypt forest and woodland of southeastern Australia, *Australian Journal of Ecology,* **10,** 399-419.

Recher, H. F., Milledge, D. R., Smith, P. L. and Rohan-Jones, W. G. (1983) A Transect Method to Count Birds in Eucalypt Forests, *Corella,* **7,** 49-54.

Reid, J. (1999) *Threatened and Declining Birds in the New South Wales Sheep-Wheat Belt: I. Diagnosis, Characteristics and Management*, A consultancy report prepared for the New South Wales

National Parks and Wildlife Service through the Threatened Species Unit funding.

Reid, N. and Landsberg, J. (1999) Tree decline in agricultural landscapes: what we stand to lose In *Temperate Eucalypt Woodlands in Australia*(Eds, Hobbs, R. J. and Yates, C. J.) Surrey Beatty and Sons, Chipping Norton, pp. 127-66.

Reynolds, R. T., SCott, J. M. and Nussbaun, R. A. (1980) A Variable circular-plot method for estimating bird numbers, *Condor,* **82,** 309-313.

Robinson, D. (1995) The re-Generation Gap, *Land for Wildlife News,* **2,** 14-15.

Ryan, P. A. (1999) The use of revegetation areas by vertebrate fauna in Australia: a review In *Temperate Eucalypt Woodlands in Australia*(Eds, Hobbs, R. J. and Yates, C. J.) Surrey Beatty and Sons, Chipping Norton, pp. 318-335.

Saunders, D. A., Hobbs, R. J. and Margules, C. R. (1991) Biological consequences of ecosystem fragmentation: a review, *Conservation Biology,* **5,** 18-32.

Simpson, K. and Day, N. (Eds.) (1999) *Field Guide to the Birds of Australia Sixth Edition,* Penguin Books Australia Ltd.

Smith, G. K. and Verbyla, A. P. (1999) Adjusted likelihood methods for modelling dispersion in generalized linear models, *Environmetrics,* **10,** 695-709.

Specht, R. L. (1972), *The Vegetation of South Australia,* Government Printer: Adelaide, Adelaide.

Sullivan and Venning, J. (1982) *The extent and severity of tree decline in agricultural regions of SA.*, Department of Environment and Planning.

Turner, S. J., O'Neill, R. V., Conley, W., Conley, M. R. and Humphries, H. C. (1991) Pattern and scale: statistics for landscape ecology In *Quantitative Methods in Landscape Ecology*(Eds, Turner, M. G. and Gardner, R. H.) Springer-Verlag.

van der Ree, R. (2001) Home-range use by the brush-tailed phascogale (*Phascogale tapoatafa*) (Marsupialia) in high-quality, spatially limited habitat, *Wildlife Research,* **28,** 517-525.

Walker, J. and Hopkins, M. S. (1990) Vegetation In *Australian Soil and Land Survey Field Handbook*(Eds, McDonald, R. C., Isbell, R. F., Speight, J. G., Walker, J. and Hopkins, M. S.) Inkata Press, Melbourne, pp. 58-86.

Wiens, J. A. (1997) Metapopulation dynamics and landscape ecology In *Metapopulation Biology: Ecology, Genetics, and Evolution*(Eds, Hanski, I. and Gilpin, M. E.) Academic Press, San Diego, pp. 43-62.

Wilson, B. (In press) The influence of scattered paddock trees on surface soil properties: A study on the Northern Tablelands of NSW, *Ecological Management and Restoration*.

APPENDIX I Site and Tree Characteristics Recorded at Sites

Tree Characteristics	Description
Tree #	Unique Tree Number eg 1A
Tree Species	Tree Species eg Euc. camaldulensis
Tree Ht (m)	Tree Height in meters
Canopy Depth (m)	Vertical Canopy Depth
Dieback %	% of Estimated Dieback
Trunk Rubbed	Signs of Trunk Rubbing eg yes or no
Canopy Diameter	Canopy Diameter
Canopy minus Overlap (m)	Canopy Diameter minus half the overlap that exists between 2 overlapping canopies.
# Trees in clump	Number of trees in a clump of trees where canopies are overlapping
# Bees in Hollows	No of hollows containing bees
DBH (cm)	Trunk Diameter at Breast Height (1.5m)
Mistletoe % Total Canopy	% of the total canopy composed of mistletoe
Mistletoe # of Individuals	Number of individual mistletoes
Hollows	Number of **Small** (0.1cm –5cm) **Medium** (5cm – 15cm) **Large** (>15cm)

High Cover Site Characteristics	Description
Date	
Observers	
Site Type	CP/HA or URR or RS or PATCH
Plot Size	200 x 200 or 30 x 1000
Understorey	**GE** (Grassy Exotic) or **GE/GN** (Grassy Exotic/ Grassy Native min 30%) mix) or **Native Shrubs/grasses**
Structural Description	Closed Forest (70-100% foliage cover), Open Forest (30-70%), Woodland (10-30), Open Woodland (<10)
Canopy Health	Good or Poor
Patch Description	Remnant or Mixed Age or Even aged
Presence of regenerating saplings	yes or no
Floristic Description	List of dominant overstorey and understorey species

High Cover Site Characteristics	Description
Date	
Observers	
Site Type	CP/HA or URR or RS or PATCH
Plot Size	200 x 200 or 30 x 1000
Understorey	**GE** (Grassy Exotic) or **GE/GN** (Grassy Exotic/ Grassy Native min 30%) mix) or **Native Shrubs/grasses**
Structural Description	Closed Forest (70-100% foliage cover), Open Forest (30-70%), Woodland (10-30), Open Woodland (<10)
Canopy Health	Good or Poor
Patch Description	Remnant or Mixed Age or Even aged
Presence of regenerating saplings	yes or no
Floristic Description	List of dominant overstorey and understorey species

APPENDIX II Abstract from Honours Thesis (Orr, 2003)

Assessing the ecological value of scattered trees for birds in an agricultural landscape in South East South Australia

Katie-Jane Orr

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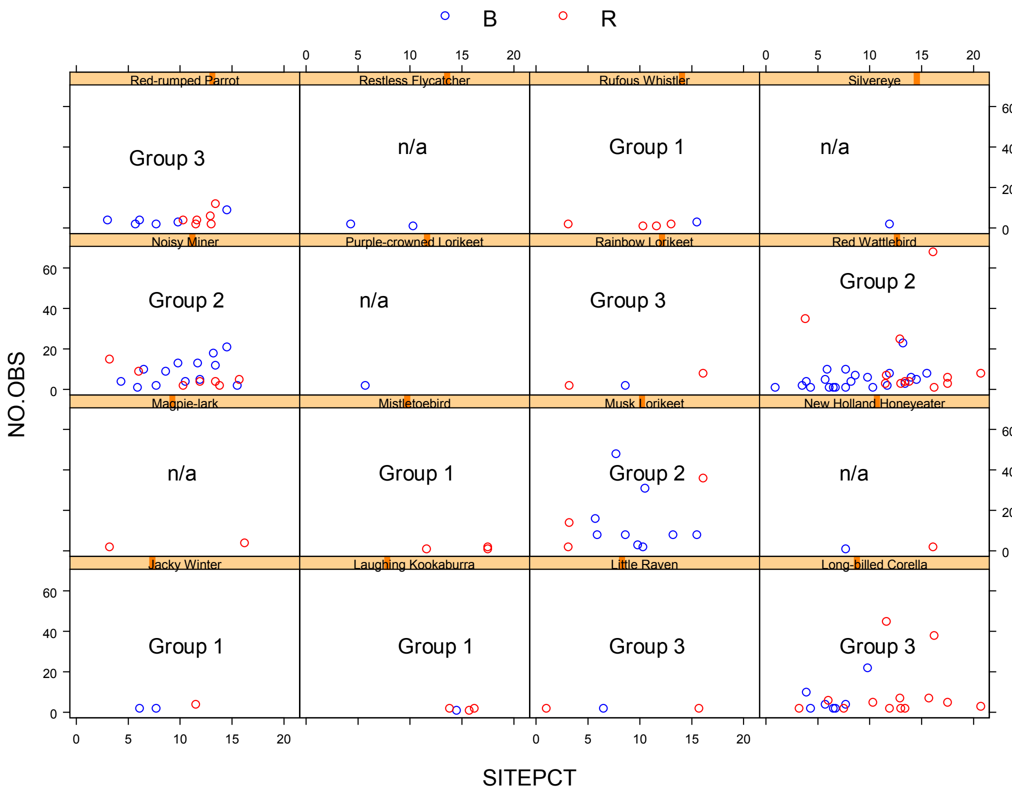
Abstract: The influence of distance of scattered trees from woodland patches on bird activity in those trees was investigated. Scattered trees at all distances up to 500 m from woodland patches were used by birds, but abundance and species richness changed with distance. Relationships were not linear; both abundance and species richness were lowest at patch edges (average of 2.5 birds and 2 species per tree) and in trees 0-100 m from patches (5 birds and 4 species per tree). They increased with distance to peak between 100 m and 300 m (8 birds and 5 species per tree), before decreasing again slightly at further distances (300-500 m) to an average of 7 birds and 5 species per tree. No single tree or landscape parameters strongly determined the presence of birds in trees, and multiple characteristics may interact to influence the use of scattered trees by birds.

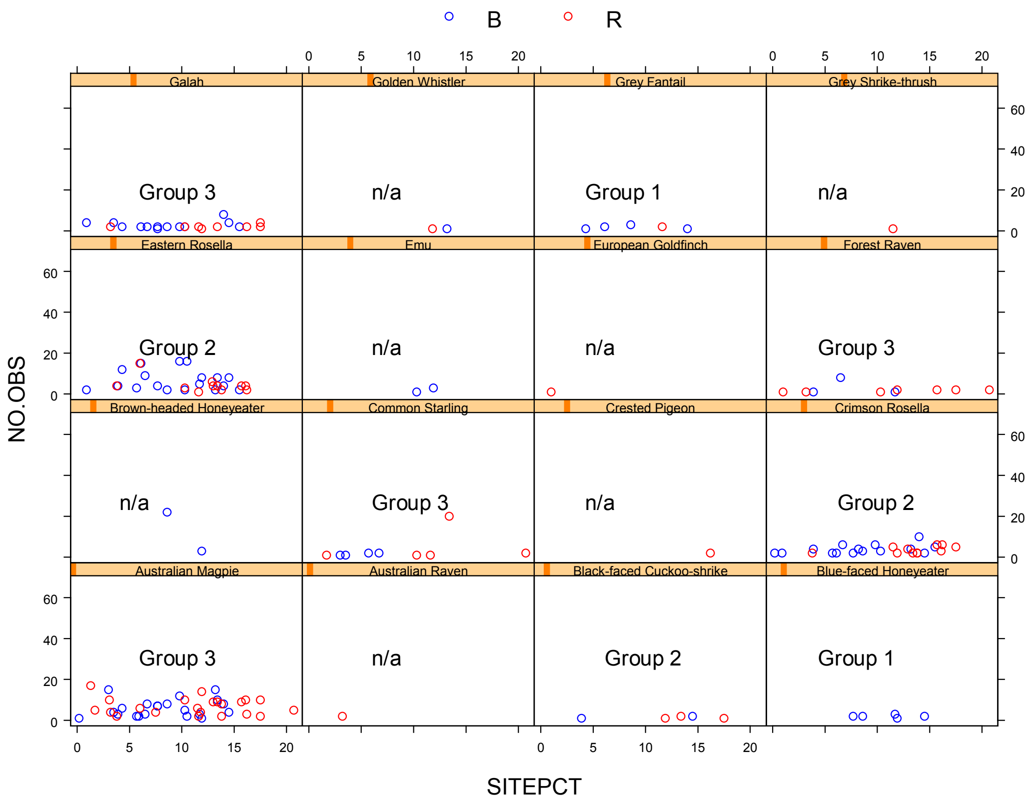
Observations of directions of bird movement between scattered trees were also made, with a greater proportion (80%) of movements directed perpendicular than parallel to patch edges. Directions of movements may have been partially determined by the location of larger woodland patches, with the birds using scattered trees as stepping stones between larger areas of habitat, and also for providing additional food or nesting resources.

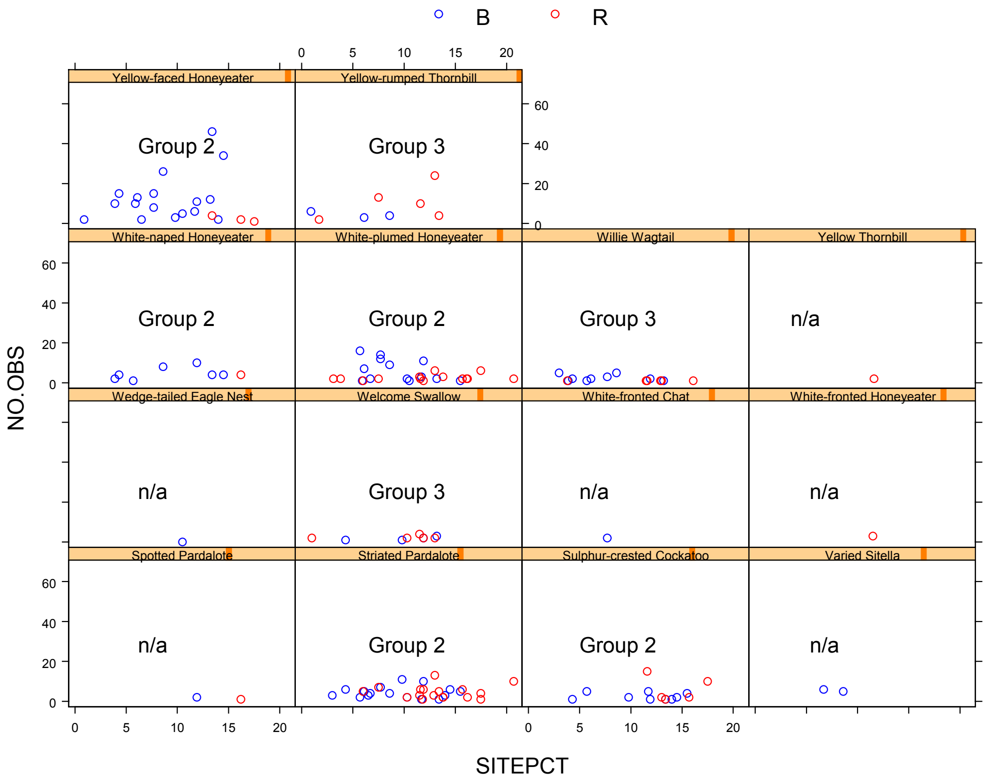
There is no simple indicator of which trees in the landscape are most valuable, and all are valuable to birds to some extent. These results have important implications for clearance assessment as they identify landscape factors as important in determining the value of scattered trees for birds.

APPENDIX III   Scatterplots of Bird Species vs Site Cover

Scatter plots used to determine which functional group species were allocated to, based on the number of sightings at sites of various % cover. Number of observations is shown on the y axis, with site % on the x axis. Blue Gum sites are in blue, Red Gum sites are in pink.




B
R
Galah
Golden Whistler
Grey Fantail
Grey Shrike-thrush
Group 3
n/a
Group 1
n/a
Eastern Rosella
Emu
European Goldfinch
Forest Raven
Group 2
n/a
n/a
Group 3
Brown-headed Honeyeater
Common Starling
Crested Pigeon
Crimson Rosella
n/a
Group 3
n/a
Group 2
Australian Magpie
Australian Raven
Black-faced Cuckoo-shrike
Blue-faced Honeyeater
Group 3
n/a
Group 2
Group 1
NO.OBS
SITEPCT


B
R
Yellow-faced Honeyeater
Yellow-rumped Thornbill
White-naped Honeyeater
White-plumed Honeyeater
Willie Wagtail
Yellow Thornbill
Wedge-tailed Eagle Nest
Welcome Swallow
White-fronted Chat
White-fronted Honeyeater
Spotted Pardalote
Striated Pardalote
Sulphur-crested Cockatoo
Varied Sitella
Group 2
Group 3
n/a
NO.OBS
SITEPCT

APPENDIX IV Bird Species Recorded at Survey Sites

		PADDOCK TREES		PATCHES	
Bird Species (Scientific Name)	**Bird Species (Common Name)**	**In Paddock Tree Sites (# of individuals)**	**Flying Over**	**In Patch (# of individuals)**	**Flying Over**
Falco longipennis	Australian Hobby		X		
Gymnorhina tibicen	Australian Magpie	X (277)	X	X (107)	
Corvus coronoides	Australian Raven	X (2)	X	X (3)	
Tadorna tadornoides	Australian Shelduck		X		X
Threskiornis molucca	Australian White Ibis		X		
Melithreptus gularis	Black-chinned Honeyeater (V)			X (4)	
Coracina novaehollandiae	Black-faced Cuckoo-shrike	X (7)	X	X (13)	
Entomyzon cyanotis	Blue-faced Honeyeater (R)	X (10)	X	X (7)	
Neophema chrysostoma	Blue-winged Parrot (V)		X		
Falco berigora	Brown Falcon		X	X (1)	
Accipiter fasciatus	Brown Goshawk		X		
Acanthiza pusilla	Brown Thornbill			X (1)	
Climacteris picumnus	Brown Treecreeper			X (16)	
Melithreptus brevirostris	Brown-headed Honeyeater	X (25)	X	X (21)	
Acanthiza reguloides	Buff-rumped Thornbill			X (8)	
Phaps chalcoptera	Common Bronzewing			X (3)	
Sturnus vulgaris	Common Starling*	X (31)	X		
Ocyphaps lophotes	Crested Pigeon	X (2)			
Falcunculus frontatus	Crested Shrike-tit (V)			X (4)	
Platycercus elegans	Crimson Rosella	X (96)	X	X (45)	
Artamus cyanopterus	Dusky Woodswallow			X (12)	
Platycercus eximius	Eastern Rosella	X (171)		X (71)	
Dromaius novaehollandiae	Emu	X (4)		X (1)	
Carduelis carduelis	European Goldfinch*	X (1)	X	X (2)	
Corvus tasmanicus	Forest Raven	X (21)	X	X (20)	X
Cacatua roseicapilla	Galah	X (54)	X	X (14)	
Pachycephala pectoralis	Golden Whistler	X (2)		X (4)	
Strepera versicolor	Grey Currawong		X	X (1)	X
Rhipidura albiscapa	Grey Fantail	X (9)		X (24)	
Colluricincla harmonica	Grey Shrike-thrush	X (1)		X (21)	
Microeca fascinans	Jacky Winter	X (8)		X (6)	
Dacelo novaeguineae	Laughing Kookaburra	X (6)		X (46)	
Corvus mellori	Little Raven	X (6)	X	X (13)	X
Anthochaera chrysoptera	Little Wattlebird			X (2)	
Cacatua tenuirostris	Long-billed Corella	X (172)	X	X (11)	X
Grallina cyanoleuca	Magpie-lark	X (6)		X (12)	
Dicaeum hirundinaceum	Mistletoebird	X (4)		X (7)	X
Glossopsitta concinna	Musk Lorikeet	X (184)	X	X (302)	X
Falco cenchroides	Nankeen Kestrel		X		
Phylidonyris novaehollandiae	New Holland Honeyeater	X (3)		X (40)	
Manorina melanocephala	Noisy Miner	X (155)		X (93)	

Bird Species (Scientific Name)	Bird Species (Common Name)	PADDOCK TREES In Paddock Tree Sites (# of individuals)	Flying Over	PATCHES In Patch (# of individuals)	Flying Over
Oriolus sagittatus	Olive-backed Oriole (R)			X (2)	
Turnix varia	Painted Button-quail (V)			X (5)	
Falco peregrinus	Peregrine Falcon (R)		X		X
Glossopsitta porphyrocephala	Purple-crowned Lorikeet	X (2)	X	X (37)	X
Trichoglossus haematodus	Rainbow Lorikeet	X (12)	X	X (6)	X
Anthochaera carunculata	Red Wattlebird	X (277)	X	X (148)	
Psephotus haematonotus	Red-rumped Parrot	X (54)	X	X (41)	
Myiagra inquieta	Restless Flycatcher	X (3)		X (10)	
Pachycephala rufiventris	Rufous Whistler	X (9)		X (37)	
Zosterops lateralis	Silvereye	X (2)	X	X (7)	
Pardalotus punctatus	Spotted Pardalote	X (3)	X	X (25)	
Threskiornis spinicollis	Straw-necked Ibis		X		
Pardalotus striatus	Striated Pardalote	X (151)	X	X (118)	
Acanthiza lineata	Striated Thornbill			X (6)	
Cacatua galerita	Sulphur-crested Cockatoo	X (52)	X	X (32)	X
Malurus cyaneus	Superb Fairy-wren			X (13)	
Gliciphila melanops	Tawny-crowned Honeyeater			X (20)	
Petrochelidon nigricans	Tree Martin		X	X (9)	X
Daphoenositta chrysoptera	Varied Sitella	X (11)		X (16)	
Aquila audax	Wedge-tailed Eagle		X	X (1)	X
Smicrornis brevirostris	Weebill			X (10)	
Hirundo neoxena	Welcome Swallow	X (19)	X	X (6)	X
Haliastur sphenurus	Whistling Kite		X		X
Coracina papuensis	White-bellied Cuckoo-shrike (R)			X (4)	
Pomatostomus superciliosus	White-browed Babbler			X (4)	
Epthianura albifrons	White-fronted Chat	X (2)			
Phylidonyris albifrons	White-fronted Honeyeater	X (3)		X (12)	
Melithreptus lunatus	White-naped Honeyeater	X (37)	X	X (45)	
Lichenostomus penicillatus	White-plumed Honeyeater	X (117)	X	X (162)	
Cormobates leucophaeus	White-throated Treecreeper			X (4)	
Corcorax melanorhamphos	White-winged Chough			X (15)	
Rhipidura leucophrys	Willie Wagtail	X (28)		X (26)	
Acanthiza nana	Yellow Thornbill	X (2)		X (15)	
Lichenostomus chrysops	Yellow-faced Honeyeater	X (227)	X	X (146)	
Acanthiza chrysorrhoa	Yellow-rumped Thornbill	X (66)		X (18)	
Calyptorhynchus funereus	Yellow-tailed Black Cockatoo				X

* Introduced

SA Status, NPW Act 1972, R = Rare, V = Vulnerable