Revegetation and Wildlife

What do we know about revegetation and wildlife conservation in Australia?

A report to Environment Australia

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Summary

There is widespread recognition in Australia of the need for revegetation to counter the detrimental effects of excessive clearing of natural vegetation. These effects include degradation of soils and water resources, decline and loss of biodiversity, loss of agricultural productivity, and increased production of greenhouse gases. Protection and management of existing natural vegetation is a critical first step, but will not be enough, on its own, to arrest ecological degradation and ensure long-term sustainability of natural resources. It is essential that vegetation cover be increased in many landscapes in Australia, either through natural regeneration or strategic replanting programs.

Revegetation activities are widespread in rural environments throughout Australia, particularly in Victoria and Western Australia, with 35% of farmers surveyed nationally in 1994 having undertaken some revegetation in the 3-year period 1991-94. The principal motivation for revegetation on farms is to provide shade and shelter for livestock and crops, and to rehabilitate or protect degraded land. However, although only 2% of recent plantings on farms were undertaken to conserve native vegetation or wildlife, more than a quarter of farmers reported that this was an important function of revegetated areas. Most revegetation is in the form of linear strips of trees (e.g. shelterbelts), and the size of revegetated areas is usually small (rarely more than 5 ha). Revegetation is predominantly carried out by using a mix of native, but not necessarily indigenous, species.

Revegetation has the potential to enhance conservation of wildlife in rural environments, but few studies have tested whether the proposed benefits are realized. Published information is sparse and largely restricted to the use of revegetation by birds. While a range of species have been recorded in revegetation, many of those resident in revegetated habitats are 'generalists' or 'open country' species that occur widely. This lack of basic monitoring and research is a critical gap in our knowledge, particularly given that revegetation activities are widespread in Australia, are supported by national environmental programs, and are promoted as having substantial benefits for biodiversity conservation.

Surveys of the occurrence of wildlife in revegetated mining sites (e.g. bauxite mines, Western Australia) show that most species typically present in adjacent unmined habitats utilise revegetated habitats. This use is related to the extent to which the restored habitat provides resources for foraging and shelter, such as leaf litter, logs, tree hollows, a diverse understorey and vegetative cover. However, there are fundamental differences between mine-site rehabilitation and revegetation in agricultural landscapes. The primary objective of revegetation on mine sites is to restore the indigenous flora and fauna, whereas most revegetation in rural landscapes has conservation as a secondary or incidental objective. Further, the spatial context of mine-site revegetation, a small area of restored vegetation surrounded by relatively undisturbed vegetation, differs markedly from the planting of trees within cleared open farmland.

The use of revegetated habitats by wildlife has been studied in a range of countries around the world, but mainly relating to linear habitats such as hedgerows, shelterbelts and plantations. A wide range of species, especially birds, have been reported using these habitats, but there has been little critical analysis of their conservation value as a habitat compared with larger blocks of vegetation or nature reserves. Clearly, they provide shelter and foraging resources for many species, and increase faunal diversity in heavily cleared landscapes. However, many species that use linear planted habitats are 'edge' species, 'generalists' or 'open country' species rather than those of greatest conservation concern. It is likely that their greatest value lies in supplementing the area of existing wooded habitats and increasing connectivity in fragmented landscapes.

Where the primary goal of revegetation is to enhance biodiversity, insights can be gained from ecological studies of remnants of natural vegetation. Characteristic features of the composition and structure of remnant vegetation, and its vulnerability to disturbance from land use, can be used for planning revegetation at the site level. Planning for revegetation at the patch or block level can be assisted by studies of the way in which wildlife communities use remnant patches of vegetation. Such studies indicate the importance of patch size and shape, the maintenance of habitat resources, and the patch location in relation to sources of disturbance. At a landscape level an important issue is the location of habitat patches in relation to other habitats, and thus the degree of isolation or habitat connectivity for populations of animals living within

revegetated blocks. These insights can be used to plan revegetation activities to increase their value as habitat, either for single species or for faunal communities.

Revegetation in rural environments offers a number of benefits for sustainable land management and agricultural productivity. Revegetation can be used to reduce land and water degradation by strategic establishment of vegetation in order to minimise the rise of saline groundwater, reduce waterlogging of soils, reduce erosion and protect water quality. These measures, together with planting of vegetation as shade and shelter for stock and crops, enhance agricultural productivity on farms. Revegetation in the form of agroforestry has the potential to provide economic benefits through a variety of timber products. By storing carbon in plant biomass, revegetation may also provide an opportunity to slow the rate of increase of greenhouse gases in Australia.

Planning revegetation projects requires careful consideration of issues such as the location of planting, selection of plant species, design of planted areas, timing of planting and the most suitable methods for establishing plants. Techniques and approaches for establishing plants in the ground appear to be the most thoroughly studied aspect of revegetation, and there is now a large and growing body of knowledge on species selection and optimum planting procedures for many areas in Australia.

There are four main areas in which future directions in revegetation can learn from past experience. First, greater emphasis needs to be given to nature conservation in the way revegetation activities are planned and implemented in rural environments. Second, there is a critical lack of knowledge of the value of revegetated habitats for flora and fauna and for maintaining ecological processes. This needs to be addressed urgently by carefully designed studies. Third, there is great potential for integrating ecological monitoring and research with on-ground activities as a way of simultaneously gaining knowledge and improving management practices. Last, strategic planning at the landscape and regional scale is required to provide a framework within which revegetation actions can most effectively contribute to local as well as regional environmental issues.

Preface

Revegetation is an important issue in natural resource management in Australia. There is widespread recognition in the community that extensive revegetation is needed to counter environmental problems arising from the loss of native vegetation. One of these problems is a decline in biodiversity in heavily developed landscapes – an ongoing loss of plant and animal species and disruption to ecological processes in which they have essential roles. Revegetation has been promoted as having substantial benefits for the conservation of biodiversity, but the reality is that this is not the main objective of most revegetation activities. In most cases, the primary motivation for revegetation is to address urgent problems in land degradation, to provide shelter for stock or crops, or to enhance the aesthetic environment.

This project was instigated by Environment Australia to identify ways in which revegetation activities can be undertaken to maximize their value as habitat for wildlife. We have addressed a number of objectives, as follows:

- to review existing information relevant to understanding the habitat requirements of native fauna and techniques for maximising habitat quality within plantations (ranging from narrow windbreaks to larger plantings);
- to provide a resource list where further information can be obtained;
- to develop technical guidelines, based on sound ecological principles, for maximising the habitat value of planted systems;
- to use case studies to illustrate how these guidelines might be applied at a range of scales;
- to develop a product for disseminating these principles, guidelines and case studies to relevant stakeholders such as landowners, Landcare and Bushcare facilitators, agroforestry officers and conservation planners.

This report fulfils the first part of the task by presenting a review of current knowledge on revegetation and wildlife conservation, together with an annotated list of references where further information can be obtained. Our focus is on the role of revegetation in the protection and maintenance of biodiversity, particularly in rural environments in southern Australia. We are primarily concerned with the way in which revegetation can be used to provide habitat for the native fauna, and thereby contribute to nature conservation in developed landscapes. Because relevant published information is scattered in the literature, the annotated list of references provides an introduction to this material for those wishing to read more widely. The second part of the task is achieved in a companion publication (Bennett *et al.* 1999) that sets out a series of principles for revegetation activities that will enhance their habitat value for wildlife. It is based upon the material reviewed in this report, but because it is intended for a wider audience less attention is given to citing scientific literature.

The report has been produced using funding from the Natural Heritage Trust, under the Bushcare Program. We thank Environment Australia for initiating the project and in particular Kathy Tracy for her support. The project was guided by a Steering Committee, comprising Kathy Tracy and Peter Lyon (Environment Australia), Geoff Barrett (Birds Australia), Stephen Platt (Flora and Fauna, NRE Victoria), Dale Tonkinson (Greening Australia Victoria) and Des Stackpole (Centre for Forest Tree Technology, NRE). We gratefully acknowledge their advice and constructive contributions. We also warmly thank those people who attended a one-day workshop in February 1999, and whose deliberations and discussion on a range of issues related to revegetation provided valuable input. They were Geoff Barrett, Karen Barton, Hugh Bramwells, Neil Collins, Ian Davidson, Louise Gilfedder, David Goldney, Ian Hislop, Richard Hobbs, Richard Loyn, Peter Lyon, David Parkes, Stephen Platt, Doug Robinson, Jim Robinson, Des Stackpole, Dale Tonkinson, Kathy Tracy and Brenan Wotherspoon. Members of the Landscape Ecology Research Group at Deakin University, Jim Radford, Rodney van der Ree, Grant Palmer and Jenny Wilson, also provided valuable comments and discussion.

1. Introduction

There is widespread recognition in Australia of the need for revegetation to counter the detrimental effects of excessive clearing of natural vegetation. The call for revegetation is coming from many sectors of the community – rural landholders, scientists, conservation organisations, state and local government agencies – and has been reflected in national policy commitments by the Commonwealth Government. In recent years, major government initiatives that have promoted revegetation activities have included the One Billion Trees Program, the National Corridors of Green Program and the Decade of Landcare (1989-1999). These, and other initiatives that promote revegetation, are now incorporated within the Natural Heritage Trust, a national program that coordinates a range of activities aimed at protecting and restoring the natural environment in Australia (Natural Heritage Trust 1999).

Revegetation activities may be undertaken for a number of reasons: to counter the degradation of land or water resources, to maintain or enhance agricultural productivity, to enhance the aesthetics of human-dominated environments, to protect and restore biodiversity and, more recently, to create carbon sinks to counter potential 'greenhouse' climate change. The focus of this report is the role of revegetation in the protection and maintenance of biodiversity, particularly in rural environments in Australia. It is primarily concerned with the way in which revegetation activities can be used to enhance habitats for the native fauna, and thus contribute to nature conservation in agricultural landscapes dominated by intensive human land use.

This report has three main objectives:
1. to present a review and synthesis of what is currently known about revegetation and its capacity to enhance habitats for wildlife in Australia;
2. to provide an introduction to relevant literature for those wishing to read more widely or gain access to primary resource material; and,
3. to form a scientific basis for developing principles for revegetation activities that will enhance wildlife habitat values. These principles are presented in a companion publication to this report (Bennett *et al.* 1999).

Introductory chapters in this report outline the need for revegetation in Australia, and review what is known about the extent and pattern of recent revegetation activities in rural environments across the country. This is followed by a summary of current knowledge of the use of revegetation by wildlife and its value as habitat. There is a scarcity of such published information in Australia, and consequently we have also included a brief review of relevant scientific literature from other countries. An alternative approach to understanding the potential value of revegetated habitats is to gain insights from the way in which wildlife species and communities use remnant stands of natural vegetation in rural environments. Consequently, studies of the status of wildlife in remnant vegetation in Australia have also been reviewed.

To provide a broader context for understanding the role of revegetation in rural environments, we have reviewed literature relating to the benefits of revegetation for sustainable land use in agricultural landscapes. A short summary is also given of sources of information concerning the planning and implementation of revegetation projects, although this topic is covered in much greater depth in other guides and books. The report concludes by discussing the effectiveness of revegetation to date, and raises issues concerning future directions for revegetation activities.

The scope of this report is largely restricted to revegetation in rural environments in Australia. It is mainly concerned with revegetation activities at a relatively small scale, such as those that typically may occur on farms or be carried out by community groups. We do not attempt to review information relating to major commercial revegetation activities, such as plantations of pines and other introduced tree species for timber, or the growing range of commercial agroforestry ventures using native species, such as the recent expansion in plantings of fast-growing eucalypts in southern Australia. Some attention is given to published results on the use by wildlife of revegetated mine sites, to compare this with revegetation activities in rural landscapes.

Selected references are cited in the text, and a list of key references and references for further reading are presented for each chapter. An annotated list of all references, including full publication details and a brief summary of the content of each, is given in the final section of the report.

Key references:

Bennett, A.F., Kimber, S.L. and Ryan, P.A. (1999). Revegetation and Wildlife: Principles for Enhancing Habitat Values for Wildlife Conservation. Environment Australia: Canberra.

Natural Heritage Trust (1999). Natural Heritage Trust Home Page. Available URL: http://www.nht.gov.au.

2. The need for revegetation in Australia

The primary reason for undertaking revegetation activities in Australia has been to counter the detrimental effects of the excessive loss of natural vegetation. Here, we briefly review the extent of vegetation loss in Australia, and the main consequences of such loss that have led to calls for restoration of vegetation.

Loss of natural vegetation

Clearing of native vegetation for agriculture, mining, forestry and human settlement is widespread throughout the world. In many regions it has been accompanied by widespread land degradation and substantial declines in biodiversity. In Australia, clearing of vegetation has occurred since the earliest days of European settlement, although the rate of clearing has been greatest in the past 50 years (Department of Environment, Sport and Territories 1995).

A snapshot of changes to terrestrial ecosystems in Australia over the last two centuries has been described in the recent State of the Environment Report (State of the Environment Advisory Council 1996):

- about 43% of forests in Australia have been cleared;
- nearly 90% of temperate woodlands and mallee have been cleared;
- more than 99% of temperate lowland grasslands in south-eastern Australia have been lost;
- about 75% of rainforests have been cleared; and
- more than 60% of coastal wetlands in southern and eastern Australia have been lost.

The most extensive loss of native vegetation has occurred in the temperate regions of the continent, particularly the fertile inland slopes and plains of south-eastern and south-western Australia that once supported diverse woodlands. These areas are now dominated by broadscale agricultural production – primarily grazing and cropping – and remnants of the former woodlands now exist as fragments of various size, shape and isolation, scattered throughout the landscape (Goldney and Bowie 1990; Hobbs and Hopkins 1990; Saunders *et al.* 1991; Hobbs *et al.* 1993; Robinson and Traill 1996; Bennett and Ford 1997).

Robinson and Traill (1996) have summarised the extent of change in a number of regions:

- in the Western Australian wheatbelt (14 million ha), only 7% is now covered by native vegetation;
- in South Australia, native vegetation remains on only 2% of the 1.5 million ha Narracoorte Plains and 9% of the 3.4 million ha Murray-Darling region;
- in the Victorian Murray-Darling region, only 9% of 3.3 million ha retains native vegetation;
- in Victoria's Box-Ironbark region, 19% of 3.7 million ha has native vegetation remaining; and
- in the Riverina region of New South Wales, 9% of 3.4 million ha still has native vegetation cover.

The extent of clearing of native vegetation has been increasingly recognised as a primary factor in land degradation in rural regions, reduced agricultural productivity and declines in biodiversity (DEST 1995). The need to restore vegetation to the landscape has, therefore, become widely accepted.

Implications of the loss of natural vegetation

Clearing of natural vegetation to establish farmland has been essential to the development of Australia's agricultural industries. However, the excessive and near-complete loss of natural vegetation in many districts has led to major environmental problems including degradation of land and water resources, increased production of 'greenhouse gases' (e.g. carbon dioxide), and the decline and loss of biodiversity in rural environments.

Degradation of land and water resources

There is abundant evidence that, in many parts of Australia, substantial degradation of the land and waterways has occurred and continues to occur. Many forms of degradation can be identified, most of which are directly associated with the excessive loss of vegetation. These include:

- *surface waterlogging* caused by rising water tables as groundwater uptake has been reduced by loss of deep-rooted vegetation;
- *salinisation of surface soils* resulting from rising water tables depositing salts in the subsoil layers;
- *loss of soil fertility* due to direct loss of topsoil by erosion, removal of nutrients by cropping, and loss of closed nutrient cycling processes;
- *soil erosion* resulting from increased wind velocity and water runoff following loss of vegetation cover;
- *erosion of stream banks* where stabilising vegetation has been removed; and
- *deteriorating water quality* of surface and groundwater supplies as a result of:
  - salinisation, where rising water tables leach salt and other minerals into water supplies;
  - siltation, where increased runoff, and erosion of slopes and stream banks deposit silt in water supplies;
  - pollution, where pesticides, herbicides, and fertilisers enter the aquatic system; and
  - eutrophication, where increased water temperatures result from removal of shading vegetation, and loss of fringing vegetation reduces the capacity to buffer the aquatic environment from inputs of nutrients and silt.

Other types of land degradation also of concern, but not directly related to vegetation clearing, include pest animal infestations, weed infestation, soil acidity, soil compaction and loss of soil structure.

Dryland salinity is a particularly widespread and increasing problem. Gretton and Salma (1996) report:

- in Victoria, 100,000 ha are affected by dryland salinity and a further 198,600 ha are considered at risk;
- in Western Australia, 900,000 ha are affected and 2.4 million ha are considered at risk; and
- in Queensland, 30,000 ha are affected and 70,000 ha are considered at risk.

Predictions are that the areas affected by salinity will continue to increase.

The extent and type of land degradation problems vary between agricultural zones – pastoral, wheat-sheep and high rainfall. Many farmers are faced with multiple land degradation problems. Figure 2-1 summarises the results of a survey of land degradation problems reported by 1800 farmers from across Australia in 1995-96 (Mues *et al.* 1998). This is likely to be an *underestimate* of the extent of these problems because degradation may not be noted until it is well advanced, and some landholders may not be aware of certain issues.

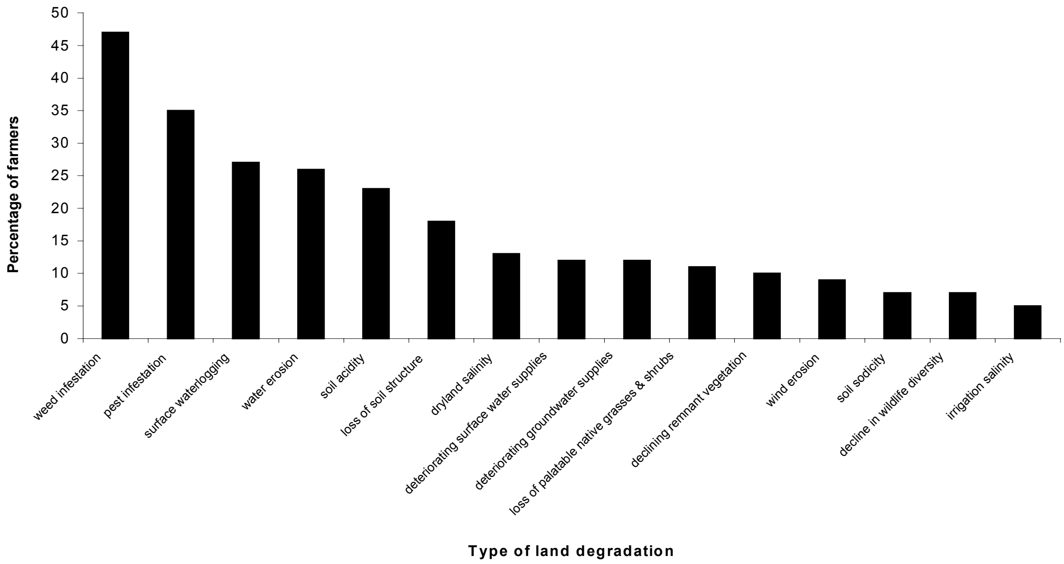

Figure 2-1. Land degradation problems reported by farmers in Australia. Values are the percentage of farmers from all broadacre and dairy industries reporting significant problems with different types of land degradation in 1995-96 (data from Mues et al. 1998).

Land degradation in some agricultural regions has advanced to a point where the future viability of production is seriously threatened and urgent measures must be taken to prevent further environmental decline.

Decline in agricultural productivity

Land degradation results in loss of productivity. Estimates of the cost of such losses, while difficult to measure, indicated that in 1995-96 the national impact was around $1 billion a year, or around 4% of the gross value of agricultural production (Mues *et al.* 1998). A more recent assessment (1997) has placed these figures at $1.2 billion per annum or 30% of total annual production costs (Lefroy and Hobbs 1998). Examples of the impact of land degradation on production in Australia include:

- at the national level, erosion has been estimated to be responsible for an annual loss of production of $80m, waterlogging $180m, soil acidity $300m, and both loss of soil structure and salinity have been attributed with a $200m loss of productivity (DEST 1995; Lefroy and Hobbs 1998);
- at the state level, in Western Australia, estimates of the annual cost of land degradation are $62m for dryland salinity, $90m for waterlogging, $70m for soil structure decline, and $21m each for water and wind erosion (Gretton and Salma 1996); and
- at the regional level, in the Lachlan Valley, NSW, the estimated production equivalent of soil loss due to sheet and rill erosion in 1989-90 was $4.27m, the equivalent of $21.1m for the Lachlan region (Gretton and Salma 1996).

Throughout the temperate woodlands, more than $400m in lost agricultural production annually has been attributed to soil degradation. It is expected that this figure will rise markedly as more than 60% of some districts become salt-affected in the next 20 years, and the area of croplands and irrigated pastures increase (Robinson and Traill 1996).

Effects on crop production

Crop yields can be affected by the extent of shelter from, or exposure to, wind. A number of examples of impacts have been reported by Reid and Bird (1990):

- *loss of soil fertility.* Exposure to strong winds has been shown to result in removal of fertile top soil. For example, about 27 t of soil was removed per ha during a five hour period in the Western Australian wheatbelt, 10% of which was the fertile top 4 mm of soil. In economic terms, removing the dust fraction from the top 8 mm of soil can reduce the yield of the subsequent crop by 25%. The rate of replacement of lost soil is only 2.5 mm in 100 years and is unlikely to occur because of continued loss.
- *physical damage to crops*. Physical damage to horticultural and vegetable crops caused by wind has been well documented. Blossom can be destroyed prior to setting, fruit discoloured or damaged, fruit fall can be increased and insect damage increased. A 37% increase in yield, and improved size and appearance of fruit, has been recorded in citrus crops in New South Wales in response to artificial shelter.

Effects on livestock production

Loss of shade and shelter provided by vegetation also contributes to declines in livestock productivity. Research in Australia has indicated that heat and cold stress can markedly reduce milk production, weight gain and stock fertility, and increase lamb, calf and off-shear mortality. Examples reported by Reid and Bird (1990) include:

- a reduction in milk production of almost 26% expected from stock exposed to high levels of solar radiation (e.g. on a 27^{o}C day); and
- a study of fine-wool merinos in the Armidale area of NSW found mortality over 30% for single lambs without shelter where windspeed exceeded 15 km/h in combination with rain or low temperatures (less than 5^{o}C) during the critical period.

Climate change and the Greenhouse effect

Greenhouse gases – carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4) – form a blanket around Earth. Light energy from the sun penetrates this blanket and is converted to heat energy at the surface. Most of this heat is re-radiated, but some is trapped by the gases in the atmosphere. This is known as the 'greenhouse effect'. It is a natural process that maintains Earth's temperature at a level necessary to support life (Australian Greenhouse Office 1998).

However, human actions such as land clearing and the burning of fossil fuels are substantially increasing the atmospheric concentrations of natural greenhouse gases. Ice core air samples have indicated that, since the Industrial Revolution (over 200 years ago), the atmospheric concentrations of carbon dioxide have increased by more than 30%, methane by more than 145% and nitrous oxide by about 15% (SEAC 1996). Humans have also created additional greenhouse gases, known as halocarbons (e.g. CFC's) (AGO 1998). Increases in concentrations of greenhouse gases have raised concerns about potential change to the global climate. This is a complex process that has been termed the 'enhanced greenhouse effect'.

Clearing of natural vegetation has been a major contributor to the enhanced greenhouse effect. It was estimated that in 1990 about 25% of the total greenhouse gas emissions in Australia resulted from land clearing. By 1995, this proportion had declined to 17%, a result explained in part by a rise in energy-related emissions, but also by a reduction in the extent of vegetation clearing (Krockenberger 1998).

Forests and woodlands play an important role in the global carbon cycle. Through photosynthetic activity, carbon dioxide from the atmosphere is transformed into inorganic material, including wood. Trees are therefore often regarded as a carbon 'sink'. Estimates suggest that forests store approximately 600 billion tonnes of carbon with a further 1,500-1,600 billion tonnes stored in soils and forest detritus (Intergovernmental Panel on Climate Change 1994 cited in Alexandra 1995). When forests are cleared, much of this carbon is converted back to carbon dioxide by burning or decomposition of organic material (AGO 1998), thereby contributing to increasing levels of greenhouse gas.

Decline in biodiversity

"Biodiversity is the variety of all life forms – the different plants, animals and micro-organisms, the genes they contain, and the ecosystems of which they form a part" (DEST 1996).

Australia contains a diverse range of biogeographic regions – the arid interior (70% of the continent), tropical monsoon areas to the north and regions experiencing mediterranean and temperate climates to the south. There are also several snow clad mountain regions, and external territories extend to subantarctic and antarctic regions. Australia's biological diversity has great scientific value and many of its elements are unique (DEST 1996).

> *"Six families of mammals, four of birds, and 14 of flowering plants are endemic – far more families than in any other country. Further, at the species level about 82 per cent of our mammals, about 45 per cent of our land birds, about 89 per cent of our reptiles, and 93 per cent of our frogs occur nowhere else.....Of the estimated 600 inshore fish species in the southern temperate zone, about 85 per cent are found only in Australia. Australia contains eight endemic families of fish, and more than half the shark and ray species are confined to Australian waters." (DEST 1996)*

However, over the last 200 years there have been profound changes to the flora and fauna in most parts of Australia. A number of species have become extinct, many species are now listed as endangered or vulnerable (Table 2-1), and a much greater number have declined, and continue to decline, in status although not officially listed as threatened species.

A number of factors have been implicated in the decline and loss of species, including the impacts of introduced species, direct destruction by humans, disease, and utilisation of natural resources, but it is widely recognised that clearing, fragmentation and degradation of natural vegetation has been the primary cause of decline. Clearing and fragmentation of natural vegetation affects the flora and fauna:

- by direct loss of habitat and reduction in population size;
- by fragmentation of habitat, and subsequent decline in small, isolated populations; and
- by disruption to, and modification of, ecological processes in remaining vegetation.

Table 2-1. The number of species listed as endangered, vulnerable or extinct in Australia under Schedule 1 of the *Endangered Species Protection Act 1992* as at 22 July 1999. (ns – not stated in report)

Taxon	Endangered	Vulnerable	Presumed extinct
Mammals	35	20	19
Birds	36	60	23
Amphibians	13	3	0
Reptiles	13	40	0
Fish	11	12	0
Invertebrates	(ns)	4	(ns)
Non-vascular plants	1	1	(ns)
Plants	370	700	68
Total	**479**	**840**	**110**

(Data from: Environment Australia 1999).

There are a growing number of reports documenting changes to the fauna in agricultural regions of southern Australia, including the wheatbelt region of Western Australia (e.g. Kitchener *et al.* 1980; Saunders 1989; Saunders and Curry 1990; Hobbs *et al.* 1993), central and northern New South Wales (e.g. Goldney and Bowie 1990; Barrett *et al.* 1994) and western and northern Victoria (Bennett 1990a; Robinson and Traill 1996; Bennett *et al.* 1998). Although it is seldom possible to show a direct cause and effect relationship between clearing of native vegetation and regional decline of fauna, it is clear that the greatest faunal changes at local, district and regional levels have occurred where there has been greatest loss of vegetation. For example, in the Northern Plains of Victoria there is a significant relationship at the landscape level between the number of woodland-dependant bird species and the extent of tree cover. There is a dramatic decline in bird species in those landscapes where less than 10% tree cover remains (Bennett and Ford 1997). Rural landscapes with little natural vegetation have a depleted fauna compared with that prior to clearing.

In many cases, the decline of species continues to occur long after the initial clearing of habitats. Populations of native animals are likely to experience further decline and extinction as fragmented populations succumb to the effects of isolation. These issues are compounded in the agricultural zone, where the conservation reserve system is inadequate and not representative of the former vegetation mosaic (Ryan in press). Presently, more than two-thirds of Australia (some 500 million ha) are managed by private landholders, compared to about 40 million ha within the terrestrial reserve system (DEST 1996). Increasingly, wildlife managers are looking towards habitats outside conservation reserves to complement the reserve system.

Summary

Clearing, fragmentation and degradation of native vegetation is a major issue in Australia, particularly in agricultural environments. The consequences of excessive land clearing include degradation of soils and water resources, decline and loss of biodiversity, increased production of greenhouse gases, and loss of agricultural productivity. Achieving ecological sustainability in land use and conservation of biodiversity in agricultural landscapes is now a major challenge facing land-use planners and land managers in Australia. Recognition of the role of vegetation cover in addressing these issues has stimulated a shift in the attitude of many planners and land managers toward the value of retaining, protecting and enhancing native vegetation in agricultural landscapes. This is of critical importance for the conservation of biodiversity. However, management of existing vegetation will not be enough on its own to arrest ecological degradation, to protect the flora and fauna, and to restore the land to a sustainable condition. It is essential that vegetation cover be increased in many agricultural landscapes through natural regeneration or strategic revegetation programs.

Key references:

Australian Greenhouse Office (1998). Factsheet: The Greenhouse Effect. Available URL: http://www.greenhouse.gov.au/pubs/factsheets/fs_effect.html (Accessed 21 April 1999).

Australian Greenhouse Office (1999). Australian Greenhouse Office Home Page. Available URL: http://www.greenhouse.gov.au.

Barrett, G.W., Ford, H.A. and Recher, H.F. (1994). Conservation of woodland birds in a fragmented rural landscape. *Pacific Conservation Biology* **1**: 245-256.

Bennett, A., Brown, G., Lumsden, L., Hespe, D., Krasna, S. and Silins, J. (1998). Fragments for the Future: Wildlife in the Victorian Riverina (the Northern Plains). Department of Natural Resources and Environment: Melbourne.

Department of Environment, Sport and Territories (1995). Native Vegetation Clearance, Habitat Loss and Biodiversity Decline: An Overview of Recent Native Vegetation Clearance in Australia and its Implications for Biodiversity. Biodiversity Series, Paper No. 6. Department of Environment, Sport and Territories: Canberra.

Department of Environment, Sport and Territories (1996). The National Strategy for the Conservation of Australia's Biological Diversity. Department of Environment, Sport and Territories: Canberra.

Environment Australia (1999). *Endangered Species Protection Act 1992* Schedules 1, 2 and 3 – 21 July 1999. Available URL: http://www.biodiversity.environment.gov.au/plants/threaten/lists/esp_lists/sched1.html (Accessed 3 Dec 1999).

Gretton, P. and Salma, U. (1996). Land Degradation and the Australian Agricultural Industry. Australian Government Publishing Service: Canberra.

Hobbs, R.J. and Hopkins, A.J.M. (1990). From frontiers to fragments: European impact on Australia's vegetation. *Proceedings of the Ecological Society of Australia* **16**: 93-114.

Mues, C., Chapman, L. and Van Hilst, R. (1998). Promoting Improved Land Management Practices on Australian Farms: A Survey of Landcare and Land Management Related Programs. ABARE Research Report 98.4: Canberra.

Reid, R. and Bird, P.R. (1990). Shade and shelter. Pp 319-335 *in* Trees for Rural Australia. (Ed. K.W. Cremer). Inkata Press: Melbourne.

Robinson, D. and Traill, B.J. (1996). Conserving woodland birds in the wheat and sheep belts of southern Australia. *Wingspan* (Supplement) **6**: 1-16.

State of the Environment Advisory Council (1996). Australia - State of the Environment 1996. CSIRO Publishing: Melbourne.

Further reading:

Alexandra (1995), Bennett (1990a), Bennett and Ford (1997), Bird *et al.* (1992), Goldney and Bowie (1990), Hobbs and Saunders (1991), Hobbs *et al.* (1993), Johnston and Williams (1993), Kitchener *et al.* (1980), Krockenberger (1998), Lefroy and Hobbs (1998), Oates (1995), Ryan (in press), Saunders (1989, 1996), Saunders and Curry (1990), Saunders and Hobbs (1995), Saunders *et al.* (1991).

3. Revegetation activities in Australia

In the broadest sense, revegetation is the deliberate planting or re-establishment of vegetation by humans. However, the term revegetation encompasses a wide range of activities that restore vegetation to land, including various forms of forestry, agroforestry, land protection and site rehabilitation (e.g. mining, dune stabilisation). Revegetation methods include allowing areas to naturally regenerate, re-establishing indigenous native vegetation by planting or direct seeding, and planting native or exotic species for a particular purpose.

A principal motivation for much revegetation in Australia has been to maintain or increase the productivity of agricultural land through protection and enhancement of soil and water quality, and by providing shelter for crops and livestock. Hence, a large proportion of revegetation in Australia is undertaken by rural landholders. However, revegetation is also undertaken by road management authorities (e.g. planting along highways), government departments (e.g. parks and land management – Parks Australia, Environment Australia), conservation groups (e.g. Australian Trust for Conservation Volunteers), forest plantation companies, mining companies, forest managers, and local government. In this chapter we review the way in which revegetation is occurring in rural Australia.

Revegetation on farms in Australia

Surveys of approximately 2000 farmers in Australia were carried out in 1994 by the Australian Bureau of Agricultural and Resources Economics (Wilson *et al.* 1995). The following summary of revegetation activities by this sector of the community is based largely on their report. Similar results were also reported in a survey conducted by CSIRO in 1995 (Nicoll and Dobbie 1996). Other than these reports, it is difficult to obtain published data summarising revegetation activities in rural environments in Australia. Given the extensive activity that is currently underway, there is a need to collate statistics at catchment and state levels on the amount, location and pattern of revegetation (including size, shape, and species composition).

Revegetation on farms is occurring throughout Australia, although the extent of involvement varies between states. Landholders in southern states have been more involved in revegetation activities over previous years than those in the Northern Territory and Queensland (Figure 3-1).

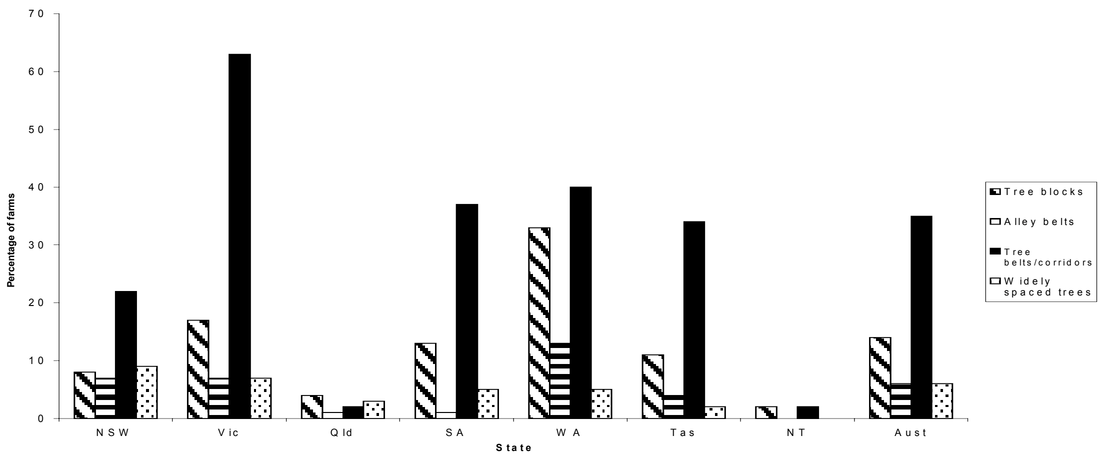

Figure 3-1. Percentage of farms with planted trees by state and planting regime (data from Wilson et al. 1995).

A similar trend is evident when the most recent (1991-94) tree planting activities are examined (Figure 3-2). Overall, 35% of farmers reported planting trees in this three year period, including 34% in the wheat-sheep zone (approx. 250-600 mm mean annual rainfall), 39% in the high rainfall zone (approx. >600 mm rainfall), and 4% in the pastoral zone (< 250 mm rainfall) (Wilson *et al.*1995).

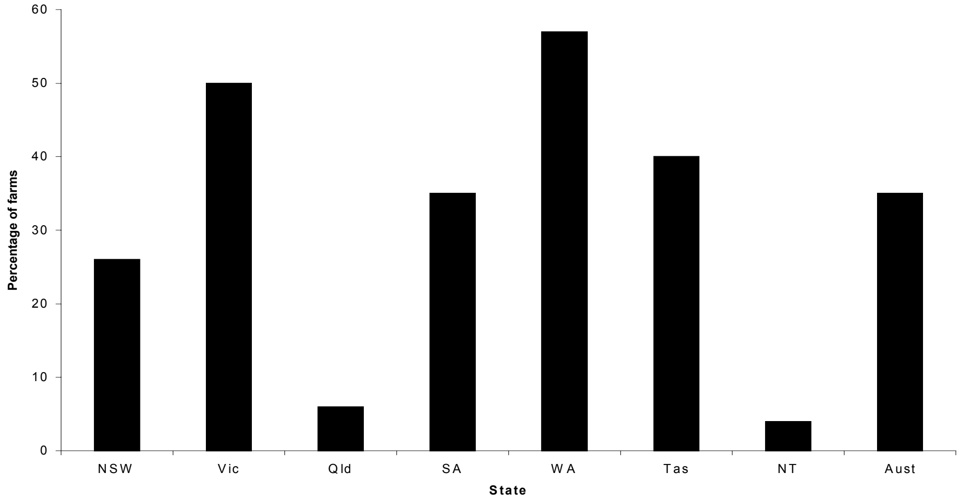

Figure 3-2. Percentage of farmers who planted trees 1991-1994 (data from Wilson et al. 1995).

The most common forms of revegetation in agricultural regions are linear strips (which may or may not connect to other patches of vegetation) and block-style plantings. Linear strips include shelterbelts, farm forestry plantations, wildlife corridors and alley farming belts; block-style plantings include agroforestry woodlots and livestock havens.

Nationally, of the farmers surveyed (Figure 3-3):

- 35% responded that they had *tree belts and corridors*: trees planted in a strip with a maximum width of approximately 30 m;
- 14% had *tree blocks* (includes woodlots): trees grown in high density clumps;
- 6% had *alley belts*: two or more strips of trees with grazing or cropping between the strips; and
- 6% had *widely-spaced plantings*: separated and scattered trees on farms, with grazing or cropping carried out between the trees.

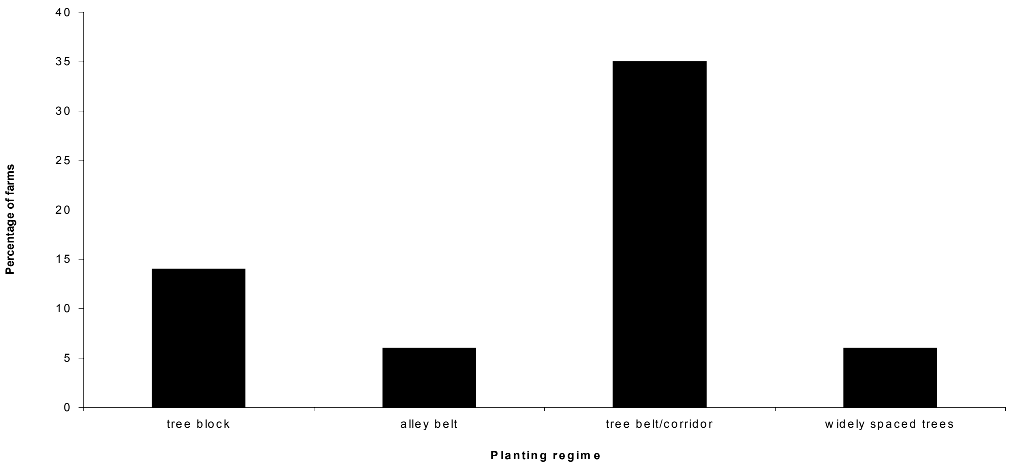

Figure 3-3. Types of revegetation plantings on farms in Australia (data from Wilson et al. 1995).

Reports from farmers with planted trees showed that the average area per farm for each planting regime was 5.2 ha of tree belts and corridors, 11.7 ha of tree blocks, 9.9 ha of alley belts (includes the area of pasture or crop between tree belts), and 406 widely-spaced trees (no measure of area reported).

Farmers were asked to list up to three main functions of planted trees on their property (Figure 3-4). In the wheat-sheep and high rainfall zones, the most common functions listed were:

- to provide shelter and shade (81% wheat-sheep; 93% high rainfall);
- to rehabilitate degraded land and/or protect land from degradation (58% wheat-sheep; 38% high rainfall); and
- to conserve native vegetation and wildlife (29% wheat-sheep; 26% high rainfall).

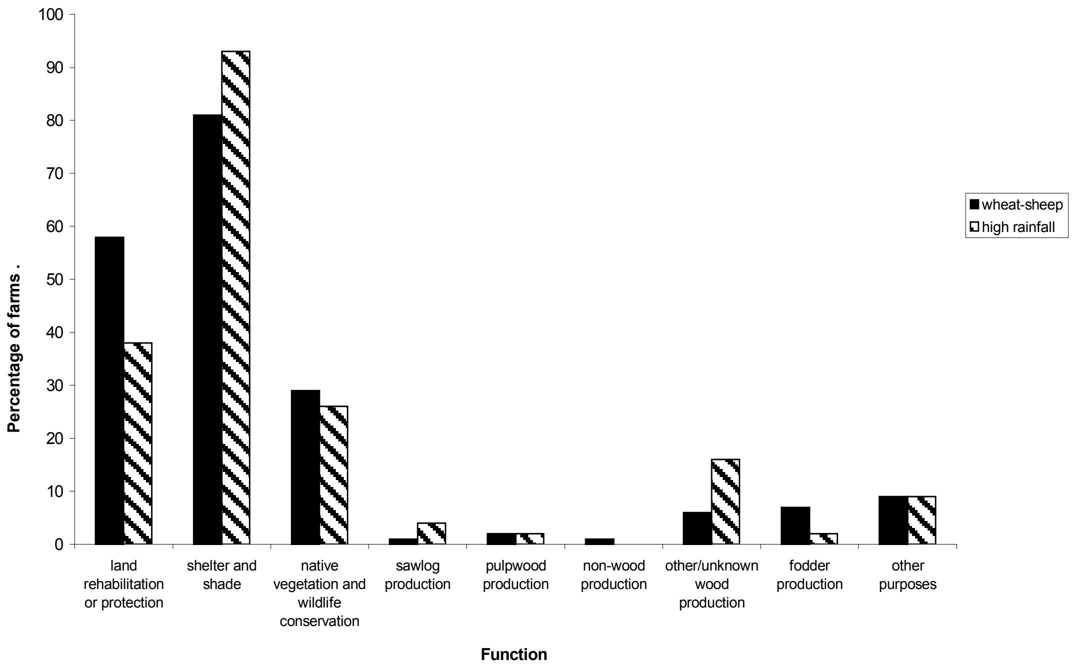

Figure 3-4. Main functions of planted trees on farms, as reported by Australian farmers (data from Wilson et al. 1995).

At the national level, planting trees to produce timber or non-timber products for sale was of relatively minor importance at the time of the ABARE survey (1994). However, in the last five years, there has been a large increase in agroforesty activities, with many plantings of blocks of fast-growing tree species on farms in southern Australia (e.g. Tasmanian Blue Gum *Eucalyptus globulus*).

Characteristics of recent plantings on farms (1991-92 to 1993-94)

Farmers with planted trees on their property were asked for detailed information about the most recent stand established during the three years 1991-92 to 1993-94 (Figure 3-5). Nationally, 63% of farmers had planted tree belts/corridors, 20% planted tree blocks, 8% planted alley belts, and 9% planted widely spaced trees.

The average area of the most recent stand of trees planted on each farm between 1991-94 was 5.1 ha for tree blocks, 3.8 ha for alley belts (including the area between tree belts), 657 trees per planting for tree belts and corridors (no measure of area reported), and 5.7 ha for widely-spaced trees.

The majority of recently established trees were local native species. For example, at the national level, 67% of farmers had established predominantly local native species, while 21% and 12% had established other native and exotic species, respectively.

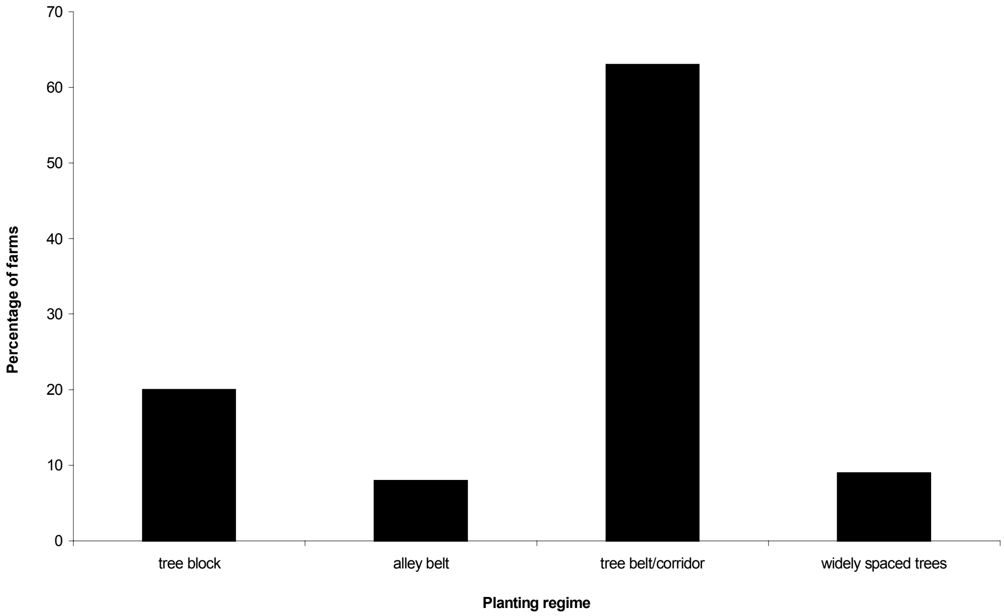

Figure 3-5. Form of the most recent (1991-1994) tree planting activities on Australian farms (data from Wilson et al. 1995).

The most commonly stated purpose for a farmer's most recent planting was (Figure 3-6):

- the provision of shade and shelter (68% of respondents);
- to rehabilitate or protect degraded land (21% of respondents); and
- to conserve native vegetation and wildlife (2% of respondents).

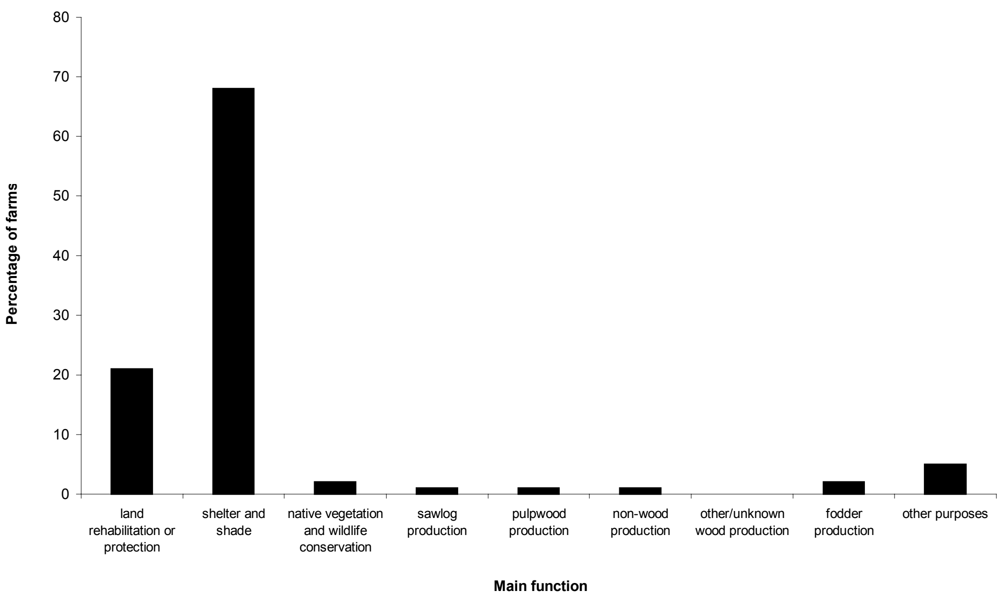

Figure 3-6. Main purpose of the most recent stand planted on farms 1991-1994 (data from Wilson et al. 1995).

Nationally, in both the wheat-sheep and high rainfall zones, less than 2% of farmers listed production of timber and non-timber products as the main function of the most recent tree plantings.

Case studies of revegetation in rural districts

Revegetation activities vary throughout Australia (Figure 3-2), and so several case studies are useful to illustrate revegetation activities at a catchment level.

1 – South Tammin Catchment, Western Australia

The South Tammin Catchment covers an area of 25,000 km^2 within the wheatbelt region of Western Australia. This region experiences a Mediterranean climate of hot dry summers and cool wet winters. Europeans progressively settled south-west Australia from 1827 and the wheatbelt now consists of an almost entirely human-modified environment. A mosaic of pastures, arable land and salt pans, with thousands of small remnants of native vegetation scattered across the landscape, now characterises most areas of the Western Australian wheatbelt (Saunders *et al.* 1993).

Revegetation in the South Tammin Catchment

Revegetation activities in the South Tammin Catchment commenced in 1982. For the first seven years a maximum of half of the 15 catchment members were involved in revegetation activities, with the area planted on an annual basis less than 50 ha. Only after dedicated funding for the catchment in 1989 did all catchment members become involved, with a subsequent boost in the area planted annually to between 100 and 300 ha (Brandenburg and Majer 1995).

Size and shape of revegetation

Most revegetated areas within the catchment are small (Figure 3-7) and linear in shape. Of the 123 revegetated areas within the catchment:

- 70% are less than five ha in size and 81% are less than 10 ha in size. Of the remaining 22 larger revegetated areas, 13 have been established primarily to enhance farm productivity (e.g. areas comprising fodder crop plantations, boudain and alley farming).
- 77% of plantations are linear in shape and comprise 63% of the total revegetated area within the catchment, while 23% of plantings are blocks and comprise 37% of the total revegetated area.

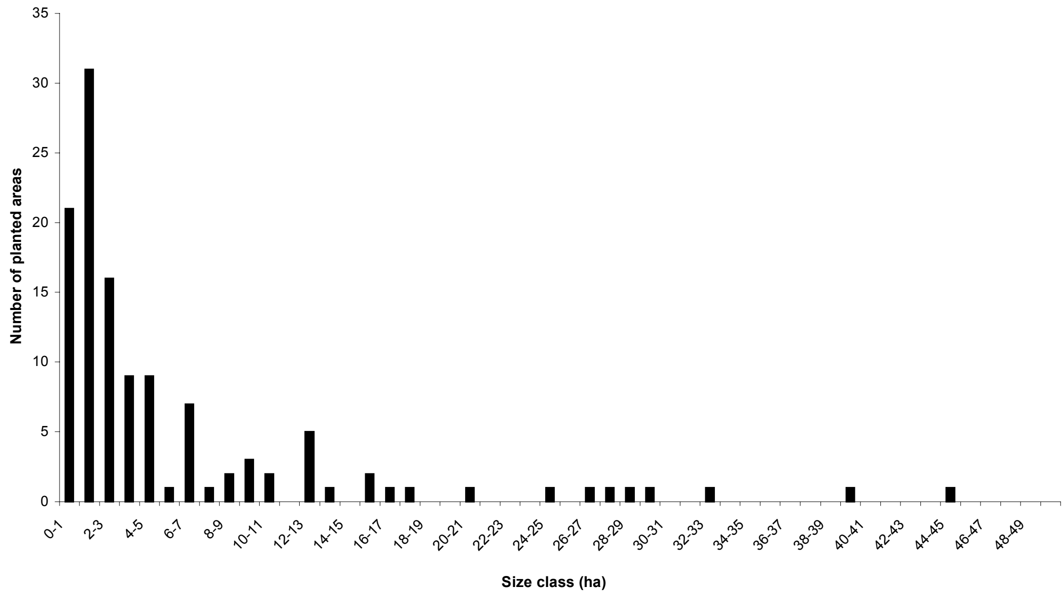

Figure 3-7. Size class distribution of revegetated areas in the South Tammin Catchment, Western Australia (redrawn from Brandenburg and Majer 1995). Note: there are two additional blocks of around 90 ha not included here.

Most revegetated areas in the South Tammin Catchment are extensions of existing remnants (68%), while 24% have no connection to remnant vegetation or other revegetated areas. Only 8% of the entire revegetated area connects at least two areas of uncleared native vegetation (Brandenburg and Majer 1995).

Species planted
A mix of native plants are present in about 70% of the total revegetated area. More than two-thirds of the areas revegetated with native plant species are characterised by native species alone, with the remaining third being characterised by the addition of tagasaste and saltbush species to the planting mix. Less than 1% is comprised entirely of local, Tammin or Western Australian natives.

Purpose and management
Revegetation within the catchment has been primarily aimed at achieving soil and water conservation rather than conservation of flora and fauna. To date, no information has been collected on the value of revegetated areas for fauna conservation. Brandenburg and Majer (1995) concluded that, in agricultural regions of Western Australia, revegetation is rarely undertaken for the primary purpose of biodiversity conservation.

2 – Goulburn Broken Catchment, Victoria

The Goulburn Broken Catchment in Victoria covers 2.4 million ha, stretching from the forested mountain ranges of the Great Dividing Range in the south, to the flat riverine plains adjacent to the Murray River in the north. The variations in geomorphology, climate and soils have produced a diversity of vegetation ranging from sub-alpine communities and tall wet forests to sparse woodlands and grasslands. European settlement began in the catchment during the late 1830's with the fertile riverine plains of the lower catchment providing suitable land for intensive agriculture. Irrigation systems were introduced in the late 1880's and now support one of the most important agricultural and food processing regions in Australia. Economic output from the irrigation region alone (approximately 20% of the catchment area) is estimated at more than $4.5 billion annually (GBCLPB 1997).

However, development of intensive agriculture has come at the expense of the natural environment. Salinity, waterlogging, soil erosion, declining water quality and loss of biodiversity are widespread problems throughout the catchment. Such widespread degradation has had a substantial impact on production and is now threatening the social, environmental and economic future of the catchment. Substantial investment is being made by government and community, working closely in partnership to address these serious issues.

Revegetation in the Goulburn Broken Catchment

The Draft Native Vegetation Management Strategy for the Catchment establishes targets for vegetation cover and outlines the need to restore depleted vegetation types to address land degradation, loss of production and biodiversity declines. Revegetation work is stimulated through a range of government funded incentive programs, as well as a substantial input from the community. Innovative cost-sharing arrangements recognise the benefits to both land owners and to the wider community and are designed to maximise the on-ground benefit. In the order of $2-$3 million is invested in revegetation and remnant habitat protection throughout the catchment each year.

Two salinity management plans for the catchment set targets for revegetation in priority areas to address hydrological cycles, productivity and water quality issues. Between 1990-1994, approximately 5000 ha of revegetation was established. At an average rate of around 1200 ha per year, the target is to establish over 40,000 ha of native vegetation to control rising groundwater and other land degradation issues. In addition, approximately 400 ha of farm forestry sites are being established per year, with predictions that this will rise rapidly in the near future as industry investment in farm forestry increases.

Design of revegetation
While the rates of revegetation for the Goulburn Broken Catchment as a whole are high, with many landowners participating, the amount of revegetation carried out on individual properties is low. For example, in the intensive irrigation region the average size of revegetated areas is 1.2 ha. Most sites are narrow linear strips to provide shade and shelter, with 2-3 rows of mainly native trees and shrubs.

Landowners suggest that loss of production, high land value, cost of establishment and the need to incorporate revegetation into the farm layout are major reasons for limiting the size of revegetated areas.

In the more extensive dryland region of the catchment, individual plantings are generally larger, averaging approximately 2.8 ha. In this region, plantings are more variable in design and include shelterbelts, 'break of slope' plantings to intercept groundwater, woodlots, and planting to bolster the width of roadsides for threatened fauna. Farm forestry is prevalent in the higher rainfall belt of this region, with some 1100 ha of plantations established since 1996 under one government-assisted scheme. Again, however, the average area of revegetation on individual properties is relatively small (approximately 12 ha), and consists mainly of monocultures of native and introduced species.

The potential benefits of revegetation for wildlife are minor considerations for the majority of revegetation activities in the catchment. There are, however, a small number of revegetation projects where biodiversity conservation is the primary aim. Species-specific revegetation programs in particular, have attracted widespread community support, an example of which is the Superb Parrot Project.

Revegetating habitat for the Superb Parrot

The Superb Parrot Project is a revegetation and remnant fencing program initiated to address the decline of the endangered Superb Parrot *Polytelis swainsonii.* Since 1992, the project has been responsible for planting 62,000 trees and shrubs on 74 sites and erecting 54 km of fencing. Landowners and volunteers have contributed over 12,000 voluntary hours and 100 ha of land for revegetation and the protection of remnants. Most of the work has occurred along the important 'fly ways' on private land that link the parrot's feeding areas with nesting sites in nearby forested areas. By linking remnant patches and providing *Acacia* species for food trees (the Superb Parrot feeds on a range of *Acacia* seeds) private landowners and agencies are attempting to provide the elements for the species survival in the area. On-going monitoring has revealed that Superb Parrots are now utilising the revegetated areas for feeding and are frequently recorded flying along revegetated strips between remnants.

Summary

Revegetation activities are widespread on farms throughout Australia, particularly in Victoria and Western Australia, with 35% of farmers sampled having undertaken some revegetation in the 3 year period 1991-94. The principal motivation for revegetation on farms is to provide shade and shelter for livestock and crops, and to rehabilitate or protect degraded land. Although only 2% of recent plantings on farms were undertaken to conserve native vegetation or wildlife, more than a quarter of farmers (29% in the wheat-sheep zone and 26% in the high rainfall zone) reported that this was an important function of revegetated areas. Most revegetation on farms is in the form of linear strips of trees (e.g. shelterbelts), and revegetated areas (either linear strips or blocks) are usually small in size (rarely more than 5 ha). Revegetation is predominantly carried out by using a mix of native species, but not necessarily species indigenous to that area. Case studies of revegetation from catchments in WA and Victoria confirm the results from a national survey – that revegetation activities on farms are overwhelmingly carried out for reasons related to agricultural production, are mainly linear strips, and are predominantly small areas.

Key references:

Brandenburg, S.A. and Majer, J.D. (1995). A database for revegetated areas in the Tammin region of Western Australia: implications for land owners, managers and researchers. Pp 258-270 *in* Nature Conservation 4: The Role of Networks. (Eds. D.A. Saunders, J.L. Craig and E.M. Mattiske). Surrey Beatty and Sons: Chipping Norton, New South Wales.

Goulburn Broken Catchment and Land Protection Board (1997). Regional Catchment Strategy. Goulburn Broken Catchment Management Authority: Shepparton.

Nicoll, C.L. and Dobbie, M.J. (1996). The CSIRO National Farm Tree Survey. Technical Memorandum 96.26. CSIRO Division of Water Resources: Canberra.

Saunders, D.A., Hobbs, R.J. and Arnold, G.W. (1993). The Kellerberrin project on fragmented landscapes: a review of current information. *Biological Conservation* **64**: 185-192.

Wilson, S.M., Whitham, J.A.H., Bhati, U.N., Horvath, D. and Tran, Y.D. (1995). Trees on farms – survey of trees on farms: 1993-94. ABARE Research Report 95.7. Australian Bureau of Agricultural and Resources Economics: Canberra.

4. Revegetation as a habitat for wildlife in Australia

There are frequent references to the value of revegetation for biodiversity in rural environments (e.g. Hobbs 1993a; Oates 1995; Bennett and Platt 1996), but there is little empirical data clearly documenting the use of revegetated areas by fauna in Australia. This is a critical deficiency considering the intensive effort now being directed towards revegetation in Australia, and the frequent assumption that revegetation will have great benefits for biodiversity. Greater attention has been given to the use of revegetated and restored areas where mining has occurred, and this literature is also briefly reviewed. However, there are major differences between revegetated habitats in rural and mining landscapes and these are also discussed below.

Potential benefits of revegetation for wildlife

There are several ways in which revegetation can be undertaken to provide conservation benefits for wildlife (Hobbs 1993a; Lambeck 1999). *Direct* measures are those that provide direct benefits to wildlife by providing habitats in which species may live or from which they obtain resources such as food and shelter. *Indirect* measures are those that do not necessarily provide an immediate benefit to wildlife species, but by preventing the decline and degradation of wildlife habitats they indirectly benefit the species that use these habitats. Direct and indirect benefits from revegetation are not mutually exclusive – both may be achieved depending upon the way in which revegetation is planned and undertaken.

Direct measures

There are three ways in which revegetation can directly benefit wildlife species (Figure 4-1):

- by increasing the *amount* of suitable habitat in the landscape, either by adding to existing vegetation or by establishing new blocks of habitat;
- by improving the *quality* of existing habitats by selective replanting or seeding of additional plant species, to enhance the composition or structure of existing vegetation (e.g. adding understorey shrubs where only a tree layer is present); and
- by promoting the *connectivity* of existing habitats in the landscape by filling in ‘gaps’ to complete the continuity of an existing link (e.g. roadside or streamside vegetation), establishing a new habitat corridor to link several habitats, or providing ‘stepping stones’ between two habitats.

Figure 4-1. Means by which revegetation can directly benefit wildlife species: 1) increasing the amount of habitat, 2) improving quality of existing habitat, or 3) connecting existing habitats.

Indirect measures

Revegetation can be used to protect or enhance *existing* habitats in several ways:

- by acting as a buffer for existing vegetation to counter micro-climatic changes at the edge of the stand (such as wind speed, exposure to sun), and to minimise impacts from surrounding land uses (such as fertiliser drift, invasion by weeds or pest animals); and
- by stabilising disturbance processes in surrounding lands to prevent the entire landscape (including wildlife habitats) from being degraded. Revegetation to counter soil erosion and drift, waterlogging and rising saline water tables will increase the sustainability of the landscape and reduce the likelihood that natural habitats will be further degraded or lost.

Key references:

Hobbs, R.J. (1993a). Can revegetation assist in the conservation of biodiversity in agricultural areas? *Pacific Conservation Biology* **1**: 29-38.

Lambeck, R.J. (1999). Landscape Planning for Biodiversity Conservation in Agricultural Regions: A Case Study from the Wheatbelt of Western Australia. Biodiversity Technical Paper No. 2. Department of the Environment and Heritage: Canberra.

Faunal use of revegetation in agricultural landscapes

While it is recognised that revegetation has the potential to benefit wildlife, little is known about the use of revegetated habitats in agricultural landscapes by either the vertebrate or invertebrate fauna.

Vertebrates

Birds

Several reports provide information on the use of revegetated habitats by birds in Australia (Biddiscombe 1985; Ryan 1993; Crome *et al.* 1994; Leary 1995). Biddiscombe (1985) recorded the avifauna of four revegetated sites in south-west Western Australia over a seven year period from the time of planting. Ryan (1993) censused the avifauna of 24 revegetated strips and five stands of remnant roadside vegetation over a single seasonal cycle in northern Victoria. The study by Crome *et al.* (1994) included four windbreak plantings in north Queensland as part of a larger study of the fauna of remnant habitat in farmland. Leary (1995) censused and compared the avifauna of planted vegetation, remnant vegetation and cleared agricultural land in the Monarto region of South Australia.

Several further studies are in progress, for example:

- an investigation of birds in windbreaks/corridors in the Northern Tablelands of NSW being conducted by Cilla Kinross (University of Sydney);
- a study of the avifauna of revegetated sites in northern Victoria being undertaken by Paul Ryan (Deakin University); and
- a community-based study involving surveys of birds in different types of vegetation on farms, including revegetated habitats (Birds on Farms Scheme, Birds Australia).

Evidence indicates that revegetated areas provide habitat for a wide range of bird species; from the studies reviewed, at least 112 species have been recorded using planted vegetation, and anecdotal evidence suggests that many other species will utilise revegetated areas (Ryan in press). However, most of those species recorded from revegetated areas are regarded as ‘generalist’ species that occur in a wide range of habitats, or as ‘open country’ species that are able to live in modified habitats amongst farmland. Seasonal fluctuations in species diversity and abundance within revegetated habitats are evident. This seasonal change and the occurrence of many species represented by only a few sightings suggests that many species of birds are able to locate revegetated plots during movements through the landscape. Whether they are *resident* within revegetation depends upon the size and suitability of the habitat.

The pattern of occurrence of birds in revegetated areas has been found to be positively associated with a number of inter-related factors:

- *age of revegetated habitats:* Bird species diversity increases with habitat age as the structure of planted vegetation develops. For example, preliminary results of the Birds on Farms survey indicate that about six species are present per half hectare in areas with trees about three years old, while more than 13 species are present per half hectare in seven year old plantings (Francis 1997).
- *structural complexity:* Bird species diversity and abundance increases with structural complexity and vegetation density, because more layers provide a greater range of potential nesting sites, shelter and food sources. Structural complexity develops with age and also depends on the plant species present (floristic diversity).
- *floristic diversity:* Bird species diversity generally increases with the number of plant species present within revegetated habitats, because a variety of plant species may provide a range of food and shelter sources year-round or at specific times of the year.
- *season:* Changes in bird communities in revegetation have been associated with seasonal events such as migration periods and the flowering of eucalypts.

At a broader scale, increases in bird species diversity have been reported on a number of properties where revegetation has increased the area of habitat available to birds. Two examples have been noted from properties in Victoria:

(1) As part of a 'Wildlife on Farms' demonstration project (forerunner to the Land for Wildlife scheme), Alan and Mary Burgess invited several government agencies to create wildlife habitat on their property, a 35 ha dairy farm in irrigated farmland near Shepparton. The project began in the late 1970s and regular bird counts recorded a subsequent increase in the total bird species known from the property from 24 species in 1979 to 110 species in 1992 (Clugston 1992).

(2) John and Cicely Fenton on 'Lanark' at Branxholme, western Victoria, have been committed to a long-term plan of tree planting and restoration of wetlands since the early 1960s (Campbell 1991). Over the years, they have transformed 18% of their 800 ha property to timber or wetland with over 80,000 trees planted in belts, clumps, agroforestry plots and along waterways and swamp verges (O'Neill 1999). The bird population has burgeoned, with the number of native species recorded from the property increasing from some 39 species in 1956 to 155 resident or itinerant species by 1996 (O'Neill 1999).

Key references:

Biddiscombe, E.F. (1985). Bird populations and farm plantations in the Hotham River Valley, W.A. *Western Australian Naturalist* **16**: 32-39.

Crome, F., Isaacs, J. and Moore, L. (1994). The utility to birds and mammals of remnant riparian vegetation and associated windbreaks in the tropical Queensland uplands. *Pacific Conservation Biology* **1**: 328-343.

Francis, J. (1997). Revegetation brings back the birds: survey backs benefits. *Australian Farm Journal* **June**: 66-67.

Leary, D.E. (1995). An ecological assessment of the Monarto Revegetation Program. B.App.Sc. (Hons) Thesis. Department of Zoology, University of Adelaide: Adelaide.

O'Neill, G. (1999). Renaissance on Lanark. *Wingspan* (Supplement) **9**: 1-16.

Ryan, P.A. (1993). The utilisation of natural and planted linear habitats by birds in northern Victoria. B.Sc. (Hons) Thesis. School of Ecology and Environment, Deakin University, Melbourne.

Ryan, P.A. (in press). The use of revegetated areas by vertebrate fauna in Australia: a review. Chapter 19 *in* Temperate Eucalypt Woodlands in Australia: Biology, Conservation, Management and Restoration. (Eds. R.J. Hobbs and C.J. Yates). Surrey Beatty and Sons: Chipping Norton, New South Wales.

Further reading:

Campbell (1991), Clugston (1992), Oates (1995).

Mammals

Published information on use of planted vegetation by native mammals is currently restricted to a survey of a single windbreak in northern Queensland in which no ground-dwelling or arboreal mammals were found.

Key reference:

Crome, F., Isaacs, J. and Moore, L. (1994). The utility to birds and mammals of remnant riparian vegetation and associated windbreaks in the tropical Queensland uplands. *Pacific Conservation Biology* **1**: 328-343.

Reptiles and amphibians

No studies have yet been published on the use of revegetation by Australia's herpetofauna in agricultural landscapes.

Invertebrates

Limited information is available on the use of revegetation by invertebrates. Trees were found to facilitate an increase in richness of soil fauna in agricultural landscapes on the Northern Tablelands, New South Wales (Chilcott *et al.* 1997). Revegetated sites in the Monarto region of South Australia were found to support 23 orders of surface-active, flying and tree-dwelling invertebrates compared with 24 orders in remnant vegetation and 21 in cleared agricultural land. Relative abundance of invertebrates was highest in cleared paddocks and lowest in the remnant vegetation (Leary 1995).

Key references:

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. Pp 378-386 *in* Conservation Outside Nature Reserves. (Eds. P. Hale and D. Lamb). The University of Queensland: Brisbane.

Leary, D.E. (1995). An ecological assessment of the Monarto Revegetation Program. B.App.Sc. (Hons) Thesis. Department of Zoology, University of Adelaide: Adelaide.

Summary

Revegetation has the potential to enhance the conservation of wildlife in rural environments in a number of ways, but there have been few studies to test whether the proposed benefits are realized. Published information is restricted to several studies of the use of revegetation by birds. These show that, while a wide range of species have been recorded in revegetation, many of those resident in revegetated habitats are 'generalists' or 'open country' species that occur widely. This lack of research and published information is a critical gap in our knowledge, particularly given that revegetation activities are becoming increasingly widespread in Australia, are being supported by millions of dollars of funding by national environmental programs, and are being promoted as having great benefits for biodiversity conservation.

Wildlife and revegetation in mining landscapes

Use of rehabilitated mine sites by vertebrates and invertebrates has been studied at several locations in Australia, particularly following bauxite mining in the Jarrah *Eucalyptus marginata* forests of Western Australia, which is used as a primary example in this review (Kabay and Nichols 1980; Majer *et al.* 1984; Nichols and Watkins 1984; Majer and Bamford 1985; Nichols and Burrows 1985; Majer 1989; Nichols *et al.* 1989; Majer 1990). Other studies have included the occurrence of selected faunal groups following mining in the Northern Territory (Majer 1983, 1985), sand mining in coastal New South Wales (Fox and Fox 1984), and following coal mining in heathland at Anglesea, Victoria (Kentish 1983).

Vertebrates

Birds

The avifauna of revegetated plots on rehabilitated bauxite mines in the Jarrah forests of Western Australia have been the subject of several studies (Kabay and Nichols 1980; Nichols and Watkins 1984; Collins *et al.* 1985). These studies found that sites revegetated as recently as 4-5 years with a wide range of understorey species can support similar numbers (over 80%) of bird species, in similar densities and diversities, to unmined sites in upland Jarrah forest:

- 12 species were found nesting in rehabilitated sites (primarily those that nest in shrubs and lower canopy foliage); and
- 21 species used rehabilitated sites for foraging or hunting.

Species richness, density and diversity of birds were positively associated with a dense understorey and midstorey, and plant species diversity.

Bird species not found in rehabilitated areas included those that are migratory, dependent on forests with mature trees, rare or present only in low densities in the surrounding Jarrah forest. For example, Nichols and Watkins (1984) noted several species absent from revegetation:

- the Rufous Treecreeper *Climacteris rufa* which would be expected to utilise rehabilitated areas when bark and leaf litter have sufficiently developed to support suitable insect populations and when tree hollows for nest sites are available;
- species such as Willie Wagtail *Rhipidura leucophrys* and Singing Honeyeater *Lichenostomus virescens* that are characteristic of open, cleared or inhabited areas and are not common in the surrounding forest block;
- Varied Sitellas *Daphoenositta chrysoptera* which would not be expected in rehabilitated areas until more mature trees are present; and
- migratory or nomadic species, such as the Purple-crowned Lorikeet *Glossopsitta porphyrocephala* and Sacred Kingfisher *Todiramphus sanctus*, that were not common in surrounding Jarrah forest and may utilise rehabilitated areas when flowering eucalypts and insects become more abundant.

In all surveys, certain species (e.g. Grey Fantail *Rhipidura fuliginosa*, Striated Pardalote *Pardalotus striatus*, Western Rosella *Platycercus icterotis*) were found in rehabilitated areas in densities lower than those in unmined forest. As most bird species in the northern Jarrah forest were found to use rehabilitated areas it was concluded that such areas will not prove an ecological barrier to species movement (Nichols and Watkins 1984).

Key references:

Collins, B.G., Wykes, B.J. and Nichols, O. (1986). Recolonisation of restored bauxite minelands by birds in southwestern Australian forests. Pp 341-354 *in* Birds of Eucalypt Forests and Woodlands: Ecology, Conservation, Management. (Eds. A. Keast, H.F. Recher, H. Ford and D. Saunders). Surrey Beatty and Sons: Chipping Norton, New South Wales.

Kabay, E.D. and Nichols, O.G. (1980). Use of Rehabilitated Bauxite Mined Areas in the Jarrah Forest by Vertebrate Fauna. Environmental Research Bulletin No. 8. Alcoa of Australia Limited: Perth.

Nichols, O.G. and Watkins, D. (1984). Bird utilisation of rehabilitated bauxite minesites in Western Australia. *Biological Conservation* **30**: 109-131.

Mammals

Surveys in rehabilitated bauxite mine sites recorded most of the four introduced and eight native mammal species (excluding bats) known to use upland Jarrah forests (Kabay and Nichols 1980; Nichols *et al.* 1989). The Southern Brown Bandicoot *Isoodon obesulus* was the only species not found using the rehabilitated area, but individuals were trapped within 20 m of the site.

Key references:

Kabay, E.D. and Nichols, O.G. (1980). Use of Rehabilitated Bauxite Mined Areas in the Jarrah Forest by Vertebrate Fauna. Environmental Research Bulletin No. 8. Alcoa of Australia Limited: Perth.

Nichols, O.G., Wykes, B.J. and Majer, J.D. (1989). The return of vertebrate and invertebrate fauna to bauxite mined areas in south-western Australia. Pp 397-422 *in* Animals in Primary Succession: The Role of Fauna in Reclaimed Lands. (Ed. J.D. Majer). Cambridge University Press: Cambridge.

Reptiles and amphibians

Over 75% of reptiles (17 of 23 species) and 75% of frogs (six of eight species) found in upland Jarrah forest in Western Australia were recorded in rehabilitated bauxite mine sites (Kabay and Nichols 1980; Nichols and Bamford 1985). Utilisation of revegetated mine sites by reptiles and amphibians was found to depend largely on food availability and the microhabitat preferences of particular species. Generally, the return of reptiles and amphibians was positively associated with leaf litter accumulation, log abundance, and availability of open foraging space.

Those reptiles not found in rehabilitated areas were species that favour thick understorey, abundant leaf litter or dense ground cover (Nichols and Bamford 1985). It is expected that as these resources become available, reptiles not currently present will return to rehabilitated mine sites. For example:

- arboreal foragers, such as the Marbled Gecko *Phyllodactylus marmoratus*, should utilise rehabilitated areas as trees mature and bark develops; and
- suitable habitat for species of legless lizard and blind snakes (e.g. Burton's Legless Lizard *Lialis burtonis* and Mitchell's Short-tailed Snake *Unechis nigriceps*) should become available as leaf litter increases, logs build up, the abundance of other small reptiles and termite mounds increase, and Grass Trees *Xanthorrhoea* spp. are introduced.

Those species found at lower densities in rehabilitated areas than in healthy unmined Jarrah forest are also expected to become more abundant as resources develop. For example, reptiles such as:

- *Ctenotus labillardieri* and *Egernia napoleonis* should increase in number as logs become more abundant; and
- *Morethia obscura* and *Lerista distinguenda* should become more abundant as trees mature and leaf litter accumulates.

Key references:

Kabay, E.D. and Nichols, O.G. (1980). Use of Rehabilitated Bauxite Mined Areas in the Jarrah Forest by Vertebrate Fauna. Environmental Research Bulletin No. 8. Alcoa of Australia Limited: Perth.

Nichols, O.G. and Bamford, M.J. (1985). Reptile and frog utilisation of rehabilitated bauxite minesites and dieback-affected sites in Western Australia's jarrah (*Eucalyptus marginata*) forest. *Biological Conservation* **34**: 227-249.

Invertebrates

Invertebrate utilisation of revegetated bauxite mine sites has also been investigated (Nichols and Bunn 1980; Majer *et al.* 1984; Nichols and Burrows 1985; Nichols *et al.* 1989; Greenslade and Majer 1993). In general, the return of ground invertebrates is enhanced by provision of dense litter cover, larger logs, and dense and diverse plant cover.

Predatory invertebrates

Utilisation of rehabilitated mine sites by predatory invertebrates (arachnids, centipedes, earwigs, cockroaches and ants) was found to vary depending on the ecological requirements of the groups concerned (Nichols and Burrows 1985). Presence of predatory invertebrates was generally positively associated with the presence of logs and dense leaf litter, shrubs, small amounts of cover, and open spaces.

Arachnids

A study of spiders, harvestmen and scorpions revealed that it may take a minimum of 8 years for populations to reach a richness comparable to forests (Nichols *et al.* 1989). Return of arachnids was positively related to vegetation structure (percentage ground cover and number of shrubs over 1.5 m), and leaf litter depth.

Termites

Return of termite species in revegetated habitats was found to be a successional process with species which feed on sound wood first appearing. With increasing age of revegetation, species which feed on decaying wood, and litter and grass-eaters also return (Nichols and Bunn 1980). Most species were present by 12 years after disturbance. Age of revegetated habitat seems to be the most important determinant of termite species composition. The abundance of termites in rehabilitated mine sites was positively influenced by the amount of litter, and small logs and other wood materials.

Ants

A study of 30 rehabilitated bauxite mine sites and three control sites in unmined forest recorded 42 species of ants in rehabilitated areas, although many of the original forest species were not present (Majer *et al.* 1984). Species richness and diversity was positively associated with plant species richness and diversity, time since rehabilitation, percentage plant cover, and percentage litter cover. Species composition of the ant community in rehabilitated areas was influenced by these same factors (Majer *et al.* 1984).

Seventy-two species of ants were collected from unmined Jarrah forest sites that were not recorded within rehabilitated areas (Majer *et al.* 1984). These included:

- a number which nest in dead standing timber or logs, and others which often nest under logs. The paucity of dead wood in the rehabilitated areas may explain the absence of certain species;
- specialised feeders, for example, *Cerapachys* spp. are specialised predators of other ants, *Anisopheidole* sp. may feed on termites and *Acropyga* sp. probably tends root aphids;
- litter dwelling species. While litter has been sufficient to facilitate the return of some species, its low depth and cover may still limit the presence of other species;
- species not common in the Jarrah forest, whose absence from rehabilitated areas may reflect the low chance of finding them within an immediate locality.

Collembola

A study of 30 rehabilitated bauxite mine sites and three forest plots in 1978-79 recorded 60 species of Collembola in rehabilitated areas and 28 species in forest plots; nine species found in the forest plots were not present on mined sites (Greenslade and Majer 1980). Species richness of the collembolan community in the rehabilitated areas was positively correlated with plot age (time since rehabilitation), plant species richness and diversity, and percentage plant cover. Litter depth and cover was also associated with a diverse collembolan fauna. Presence of suitable logs and other soil attributes may also be important factors determining the return of some species. Those species not collected on rehabilitated plots have habitat requirements, such as rotted logs, which may take up to 100 years to develop. While many rehabilitated plots were older than three years, results indicate that the collembolan fauna on rehabilitated areas only begins to approach that of forest plots after 10-13 years when trees attain canopy cover similar to a forest.

Key references:

Greenslade, P. and Majer, J.D. (1993). Recolonisation by Collembola of rehabilitated bauxite mines in Western Australia. *Australian Journal of Ecology* **18**: 385-394.

Majer, J.D., Day, J.E., Kabay, E.D. and Perriman, W.S. (1984). Recolonisation by ants in bauxite mines rehabilitated by a number of different methods. *Journal of Applied Ecology* **21**: 355-375.

Nichols, O.G. and Bunn, S. (1980). Termite Utilisation of Rehabilitated Bauxite Minesites. Alcoa of Australia Ltd Environmental Research Bulletin No. 9.

Nichols, O.G. and Burrows, R. (1985). Recolonisation of revegetated bauxite mine sites by predatory invertebrates. *Forest Ecology and Management* **10**: 49-64.

Nichols, O.G., Wykes, B.J. and Majer, J.D. (1989). The return of vertebrate and invertebrate fauna to bauxite mined areas in south-western Australia. Pp 397-422 *in* Animals in Primary Succession: The Role of Fauna in Reclaimed Lands. (Ed. J.D. Majer). Cambridge University Press: Cambridge.

Recommended management practices for facilitating wildlife return to revegetated sites in mining landscapes.

Recommendations for change to rehabilitation practices in bauxite mine sites to facilitate faunal recolonisation have been summarised by Nichols *et al.* (1989). They include the need to: return larger logs for shelter, increase litter cover, increase the return of woody material, increase diversity of the understorey, select trees with bark similar to Jarrah, manage the understorey by thinning, deep rip the soil to facilitate penetration of tree roots, use fire to make the structure of sites similar to unmined, upland forest, reduce the number of perimeter roads around pits, introduce nest boxes for hollow-nesting birds and mammals, and control feral animals – mainly cats.

It is notable that all of these recommendations relate to management of vegetation at the site level so that particular resources required by species are available. It will be necessary for long-term monitoring to be undertaken to confirm that all species *do* return to the rehabilitated sites as the habitat becomes more suitable with time. Because such mine sites are surrounded by unmined forest, which provides a source of colonists for the revegetation, the issue of landscape context and spatial pattern of the revegetation is of lesser importance than in agricultural landscapes (see below).

Differences between mine-site rehabilitation and agricultural revegetation practices

There are several fundamental differences between revegetation in agricultural landscapes and mine-site rehabilitation (Hobbs 1993a). First, the objectives of revegetation in areas disturbed by mining are different from that of revegetation in agricultural systems. The underlying motivation for revegetation on a mining rehabilitation site, in response to a legislative requirement or 'social' responsibility, is to restore the original biota to the site following mining. Thus, the primary goal is restoration of flora and fauna. In contrast, the aim of most revegetation projects in agricultural areas is to protect land and water resources, or provide shelter for livestock, which largely dictates the design, placement and plant species selection for revegetation at the property and catchment scale. The potential benefits of revegetation for biodiversity conservation have generally been a secondary or 'incidental' objective in most situations in rural environments.

Second, the major difference between mine-site rehabilitation and agricultural revegetation is the landscape context in which they occur. In the Jarrah forest of Western Australia, for example, sites rehabilitated following bauxite mining are surrounded by, or in close proximity to, extensive areas of native vegetation which provide a suitable source for recolonisation and maintain natural ecological processes. In contrast, agricultural revegetation is frequently surrounded by a production landscape, hostile to most faunal species, and containing only small fragments of the original vegetation dispersed across the landscape.

Successful recolonisation of revegetated sites by animals in agricultural landscapes relies on species being able to traverse the intervening matrix, with the chance of successful recolonisation decreasing as isolation of revegetated sites increases. While the careful placement of revegetated patches within networks of remnant vegetation, or the establishment of corridors may reduce these difficulties, rarely will the situation in agricultural landscapes approximate that of mine sites. Consequently, the apparently successful restoration of mine sites with functioning ecosystems that resemble the original habitat must be treated with caution when setting goals for revegetation in agricultural landscapes (Ryan in press).

Key references:

Hobbs, R.J. (1993a). Can revegetation assist in the conservation of biodiversity in agricultural areas? *Pacific Conservation Biology* **1**: 29-38.

Ryan, P.A. (in press). The use of revegetated areas by vertebrate fauna in Australia: a review. Chapter 19 *in* Temperate Eucalypt Woodlands in Australia: Biology, Conservation, Management and Restoration. (Eds. R.J. Hobbs and C.J. Yates). Surrey Beatty and Sons: Chipping Norton, New South Wales.

Summary

Studies of the use of revegetated areas by wildlife on former mining sites in Jarrah forests in Western Australia, show that a majority of species typically present in unmined forest have been recorded from revegetated sites, although their relative abundance may vary. The use of revegetated sites by most faunal groups is related to the extent to which the restored habitat provides resources for foraging and shelter, such as leaf litter, logs and woody material, diverse understorey, tree hollows, and vegetative cover. It is expected that the fauna of rehabilitated sites will increasingly match that of undisturbed sites as the vegetation ages. Two fundamental differences between mine-site rehabilitation and revegetation in agricultural landscapes mean that results from mine revegetation can not be directly extrapolated to the rural situation. The primary objective of revegetation on mine sites is to restore the indigenous flora and fauna, whereas most revegetation in rural landscapes is undertaken primarily to increase agricultural productivity with conservation as a secondary or incidental objective. Second, the spatial context of mine-site revegetation, a small area of restored vegetation surrounded by relatively undisturbed vegetation, differs markedly from revegetation within cleared open farmland.

5. Revegetation and its value for wildlife in other parts of the world

Although there are few studies of faunal use of revegetated habitats in Australia, there is a larger body of research in other countries that has examined faunal use of planted habitats in agricultural landscapes.

Types of revegetation

Planted habitats in agricultural landscapes in other parts of the world are predominantly linear features, including shelterbelts and windbreaks, hedgerows, fencerows and tree rows.

Shelterbelts and windbreaks are widespread in the Great Plains of the United States, the Soviet Union, China and Japan. Their structure and composition vary greatly but they generally consist of rows of woody plants that have been deliberately planted by humans for a variety of purposes, including shelter from wind, to reduce soil erosion, as a source of timber, for wildlife habitat and for their aesthetic qualities. These plantings may be a monoculture of non-indigenous tree species or a mixture of indigenous trees and shrubs that mimic the natural vegetation.

The use of plantings as shelterbelts and windbreaks to protect houses and farm buildings, livestock and crops from damaging winds, windchill and snow drift, and to reduce environmental degradation is common practice in agricultural landscapes throughout the world. For example:

- in the former Soviet Union, more than two million ha of shelterbelts were planted to reduce land degradation in agricultural areas (Schroeder and Kort 1989).
- in the United States, tens of thousands of kilometres of shelterbelts were established on the Great Plains earlier this century to reduce soil erosion from cropping areas (Baer 1989).
- in China, trees were planted around cropping land to prevent wind erosion as early as 550 BC. In the 1950's, 4000 km of forest belts were planted to control sand movement. In 1978, the Chinese government initiated a shelterbelt development program to form a 'Great Green Wall' of 35 million ha of trees stretching 700 km across northern China. In the last 40 years, 30 million ha of shelter-forest has been established in China with further plans being approved to control 6.7 million ha of desertified land in the next 10 years by planting trees, shrubs and grasses (Bird *et al.* 1992; Mitchell *et al.* 1998).

These shelterbelts now provide not only landscape protection benefits, but also extensive areas of potential wildlife habitat, in some cases forming important additions to the area of vegetation available to the fauna in these landscapes.

Hedgerows are widespread in Great Britain and Europe. These narrow bands of woody vegetation have been planted to form boundaries to farmland and barriers to the movement of stock between fields. Many are dominated by a single or a few woody species, although floristic diversity is enhanced by grasses and herbaceous species of the ground layer, and structural diversity by associated ditches and raised banks. Hedgerows form extensive networks linking remnant woods and forests retained within the rural landscape.

Fencerows are characteristic of farmland in eastern United States and Canada. They can either be planted or develop by regeneration and dispersal of plants in a neglected strip of land between fields. The vegetation ranges from grass and herb dominated rows, to narrow lines of shrubs, to broad strips with mature woodland trees. Woody plant species in fencerows are primarily those with wind or animal dispersed seeds, but wider fencerows may support woodland-interior species. Fencerows may form extensive corridor networks amongst farmland and between woodland patches.

Grassy field margins are characteristic of farmland in numerous countries, such as France, the Netherlands and United Kingdom. Narrow grassy strips are established either by natural regeneration or by sowing grass, and are usually cut or sprayed annually. There is a growing interest in the ecological role of such field margins, including their value as habitat for invertebrates (Mineau and McLaughlin 1996).

Plantations are usually block-style plantings (can also be linear strips) established primarily as a source of timber, although they may also provide a variety of land conservation benefits. Plantations can form extensive areas of vegetation. For example:

- an urban reafforestation plan in the Randstad region of western Netherlands, which encompasses the four largest cities (Amsterdam, The Hague, Rotterdam, Utrecht), involves the development of about 10,000 ha of forests and recreation areas over a 15 year period (Harms and Knaapen 1988).
- in Britain, an initiative to establish a National Forest is underway, with the aim being to develop a multi-purpose forest across 500 km^2 of land over three Midlands counties. It will involve planting about 30 million trees, and will have an ecological, commercial and recreational focus (Pearce 1994).

The value of these revegetated areas for wildlife or nature conservation has been investigated in a number of studies. Other values of revegetation in agricultural landscapes that have been reported include economic, recreational and aesthetic values (Baer 1989; Cable and Cook 1990; Cable 1991; Cook and Cable 1995).

Key references:

Baer, N. W. (1989). Shelterbelts and windbreaks of the Great Plains. *Journal of Forestry* **87**: 32-36.

Bennett, A.F. (1999). Linkages in the Landscape: the Role of Corridors and Connectivity in Wildlife Conservation. IUCN: Gland, Switzerland.

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

Burel, F. (1996). Hedgerows and their role in agricultural landscapes. *Critical Reviews in Plant Sciences* **15**: 169-190.

Cable, T.T. (1991). Windbreaks, wildlife and hunters. Pp 35-55 *in* Wildlife and Habitats in Managed Landscapes. (Eds. J.E. Rodiek and E.G. Bolen). Island Press: Washington DC.

Capel, S. W. (1988). Design of windbreaks for wildlife in the Great Plains of North America. *Agriculture, Ecosystems and Environment* **22/23**: 337-347.

Cook, P. S. and Cable, T.T. (1995). The scenic beauty of shelterbelts on the Great Plains. *Landscape and Urban Planning* **32**: 63-69.

Forman, R.T.T. and Baudry, J. (1984). Hedges and hedgerow networks in landscape ecology. *Environmental Management* **8**: 495-510.

Mineau, P. and McLaughlin, A. (1996). Conservation of biodiversity within Canadian agricultural landscapes – integrating habitat for wildlife. *Journal of Agricultural and Environmental Ethics* **9**(2): 93-113.

Schroeder, W. R. and Kort, J. (1989). Shelterbelts in the Soviet Union. *Journal of Soil and Water Conservation* **44**: 130-134.

Further reading:

Burel and Baudry (1990), Cable and Cook (1990), Forman (1995), Harms and Knaapen (1988), Mitchell *et al.* (1998), Pearce (1994).

Faunal use of revegetation in agricultural landscapes

In many countries, planted areas are recognised as an integral part of the landscapes in which they occur, providing important habitat for a variety of species. Indeed, concern has been raised about the potential biological impacts associated with the loss and deterioration of hedgerow and shelterbelt habitats in areas of North America, Britain, France and elsewhere (Sorenson and Marotz 1977; Forman and Baudry 1984; Conyers 1986; Baltensperger 1987; Schaefer *et al.* 1987; Burel and Baudry 1990; Cable 1991; Burel and Baudry 1995; Burel 1996).

A number of studies have shown that revegetated habitats are used by a wide range of faunal groups and contribute to the persistence of species in agricultural landscapes. Different species respond to the presence of hedgerows, fencerows, shelterbelts and windbreaks in different ways; they may be used for breeding, shelter, foraging, and movement or dispersal. Seasonal changes have also been recorded in the structure of bird, mammal, reptile, amphibian and insect communities of hedgerows (Forman and Baudry 1984).

Vertebrates

Birds

Much attention has been given to use of hedgerows, shelterbelts and fencerows as habitat for birds (Pollard *et al.* 1974; Yahner 1982a, 1982c, 1983b; Arnold 1983; Best 1983; Osborne 1984; Shalaway 1985; Lack 1988; Johnson and Beck 1988; Green *et al.* 1994; Parish *et al.* 1994, 1995; Haas 1995, 1997; Macdonald and Johnson 1995). These habitats have been found to provide access to food in adjacent fields, cover from predators, song perches, roosting sites, nesting sites, foraging habitats and movement corridors for a number of bird species around the world (see Table 5-1).

While large numbers of species have been reported using these linear habitats, primarily for shelter, temporary refuge or foraging, only a smaller group of bird species (mainly farmland, forest edge or generalist species) use these linear strips as nesting habitat. Hedgerows and shelterbelts are not a replacement for large blocks of habitat, but their presence does appear to significantly increase the diversity of birds, especially woodland species, in open farmland. Sites with hedges, ditches or linear woods have more species than comparable areas of arable land (Arnold 1983). Hedge intersections are favoured by many breeding birds in comparison with straight sections, probably because a greater area of habitat is available within a specified distance (Lack 1988).

The occurrence and richness of bird species is related to the:

- *dimension and structure of the hedgerow or fencerow*: Species respond to different aspects of hedge structure, but in general 'bird rich' hedgerows are those that are tall and wide, have many trees and species of trees, few gaps, contain dead timber, and a diverse structure.
- *associated habitats*: Habitats associated with hedgerows along field boundaries, such as ditches and wide grassy margins, also enhance the overall boundary strip for birds.
- *surrounding land use*: Land use surrounding hedges is an influential factor on their suitability as habitat. There is greater bird species richness in hedgerows where permanent pasture occurs on either side, in comparison with those with adjacent arable lands. The presence of rivers and ponds and garden habitat nearby also encourages use by birds.

Key references:

Arnold, G.W. (1983). The influence of ditch and hedgerow structure, length of hedgerows, and area of woodland and garden on bird numbers on farmland. *Journal of Applied Ecology* **20**: 731-750.

Best. L.B., Freemark, K.E., Dinsmore, J.J. and Camp, M. (1995). A review and synthesis of habitat use by breeding birds in agricultural landscapes of Iowa. *American Midland Naturalist* **134**: 1-29.

Haas, C. (1997). What characteristics of shelterbelts are important to breeding success and return rate of birds? *American Midland Naturalist* **137**: 225-238.

Hino, T. (1985). Relationships between bird community and habitat structure in shelterbelts of Hokkaido, Japan. *Oecologia* **65**: 442-448.

Macdonald, D.W. and Johnson, P.J. (1995). The relationship between bird distribution and the botanical and structural characteristics of hedges. *Journal of Applied Ecology* **32**: 492-505.

Martin, T.E. (1980). Diversity and abundance of spring migratory birds using habitat islands on the Great Plains. *Condor* **82**: 430-439.

Parish, T., Lakhani, K.H. and Sparks, T.H. (1994). Modelling the relationship between bird population variables and hedgerow and other field margin attributes. I. Species richness of winter, summer and breeding birds. *Journal of Applied Ecology* **31**: 764-775.

Shalaway, S.D. (1985). Fencerow management of nesting birds in Michigan. *Wildlife Society Bulletin* **13**: 302-306.

Yahner, R.H. (1983b). Seasonal dynamics, habitat relationships, and management of avifauna in farmstead shelterbelts. *Journal of Wildlife Management* **47**: 85-104.

Further reading:

Baudry (1989), Bennett (1999), Best (1983), Busche (1997), Emmerich and Vohs (1982), Fuller *et al.* (1997), Green *et al.* (1994), Jentzsch (1992), Johnson and Beck (1988), Lack (1988), Morgan and Gates (1982), Munteanu (1990), Osborne (1984), Parish *et al.* (1995), Petrides (1942), Pollard *et al.* (1974), Roach and Kirkpatrick (undated), Schroeder (1986), Schroeder *et al.* (1992), Sparks *et al.* (1996), Wegner and Merriam (1979), Yahner (1982a, 1982c).

Table 5-1. Examples of the use of hedgerows, shelterbelts and fencerows by faunal groups around the world.

Taxon	No. of species	Habitat	Location	Source
Birds				
Birds	93	fencerows	New York State, USA	Petrides 1942
Birds	25	shelterbelts	Hokkaido, Japan	Hino 1985
Birds	73	shelterbelts, fencerows	Iowa, USA	Best et al. 1995
Birds	37	hedgerows	eastern England	Arnold 1983
Birds	65	shelterbelts	South Dakota, USA	Martin 1980
Birds	66	hedges	Dithmarschen, Germany	Busche 1997
Birds	62	copses	Germany	Jetzsch 1992
Breeding birds	62	shelterbelts	Great Plains, Kansas, USA	Schroeder et al. 1992
Breeding birds	21	shelterbelts	Ceanu Mare, Romania	Munteanu 1990
Mammals				
Small mammals	10	hedgerows	England	Eldridge 1971; Pollard and Relton 1970; Kotzageorgis and Mason 1997
Small mammals	12	hedgerows	New York, USA	Petrides 1942
Small mammals	11	shelterbelts	Minnesota, USA	Yahner 1982b, 1983a
Small mammals	9	fencerows	Ontario, Canada	Asher and Thomas 1985
Bats	2	hedgerows, tree lines, tree lanes	Netherlands	Limpens and Kapteyn 1991; Verboom and Huitema 1997
Invertebrates				
Invertebrates	77	hedgerows, fields	England	Lewis 1969
Carabids	57	hedges (9 years old)	Bonn, Germany	Gruttke and Kornacker 1995
Carabid beetles	54	treed lane	France	Burel 1989
Carabid beetles	42	hedgerow network	France	Burel 1989
Geometrides (moths)	52	hedges	Switzerland	Lavorel 1988
Aphid eating insects	1000/m^2	field boundaries	United Kingdom	Chiverton 1991 cited in Mineau and McLaughlin 1996
Spiders	95	hedges (9 years old)	Bonn, Germany	Gruttke and Kornacker 1995
Harvestmen	9	hedges (9 years old)	Bonn, Germany	Gruttke and Kornacker 1995

Mammals

Habitats such as shelterbelts and hedgerows have been shown to facilitate movement and to provide refuge, foraging and breeding habitat for populations of some mammals (see Table 5-1). Hedgerows in Great Britain and Europe provide cover for woodland rodents such as Wood Mice *Apodemus sylvaticus* and Bank Voles *Clethrionomys glareolus* (Pollard and Relton 1970, Eldridge 1971). Other mammals using hedgerow cover include rabbits, squirrels, weasels, hedgehogs, moles, Common Shrews *Sorex araneus*, Pygmy Shrews *S.minutus*, Water Shrews *Neomys fodiens*, Field Voles *Microtus agrestis*, Brown Rats *Rattus norvegicus*, Yellow-necked Mice *Apodemus flavicollis*, Harvest Mice *Micromys minutus* and House Mice *Mus musculus* (Eldridge 1971; Pollard *et al.* 1974; Forman and Baudry 1984; Kotzageorgis and Mason 1997).

Fencerow and shelterbelt networks in North America are also used by a range of animal species (Petrides 1942; Dambach 1945; Ogilvie and Furman 1959; Wegner and Merriam 1979; Swihart and Yahner 1982; Best 1983; Asher and Thomas 1985; Shalaway 1985; Henderson *et al.* 1985; Johnson and Beck 1988; Bennett *et al.*1994). Small terrestrial mammals such as shrews, voles, rabbits and chipmunks live within suitable fencerow vegetation, while medium-sized mammals such as the Red Fox *Vulpes vulpes*, Striped

Skunk *Mephites mephitis*, Woodchuck *Marmota moxa rufescens* and Raccoon *Procyon lotor* use fencerows for foraging, refuge and movement (Bennett 1999).

Mammalian use of revegetation has been mainly associated with the structure and dimensions of the habitat. Species respond to different aspects of hedge structure, but 'mammal rich' hedgerows are generally those that are tall and wide, have a diverse and complex vegetation structure and composition, few gaps, and have logs and other dead timber. Fencerows, hedgerows and shelterbelts, on their own, are unlikely to maintain viable populations of many species. However, in conjunction with other larger areas of habitat, they have a role in maintaining wildlife, albeit mostly common species, within the farmland mosaic (Bennett 1999).

Key references:

Asher, S.C. and Thomas, V.G. (1985). Analysis of temporal variation in the diversity of a small mammal community. *Canadian Journal of Zoology* **63**: 1106-1109.

Bennett, A.F., Henein, K. and Merriam, G. (1994). Corridor use and the elements of corridor quality: chipmunks and fencerows in a farmland mosaic. *Biological Conservation* **68**: 155-165.

Johnson, R.J. and Beck, M.M. (1988). Influences of shelterbelts on wildlife management and biology. *Agriculture, Ecosystems and Environment* **22/23**: 301-335.

Kotzageorgis, G. C. and Mason, C.F. (1997). Small mammal populations in relation to hedgerow structure in an arable landscape. *Journal of Zoology(*London) **242**: 425-434.

Limpens, H. J. G. A. and Kapteyn, K. (1989). Bats, their behaviour and linear landscape elements. *Myotis* **29**: 63-71.

Petrides, G. (1942). Relation of hedgerows in winter to wildlife in central New York. *Journal of Wildlife Management* **6**: 261-280.

Pollard, E. and Relton, J. (1970). Hedges. V. A study of small mammals in hedges and cultivated fields. *Journal of Applied Ecology* **7**: 549-557.

Verboom, B. and Huitema, H. (1997). The importance of linear landscape elements for the Pipistrelle *Pipistrellus Pipistrellus* and the Serotine Bat *Eptesicus Serotinus*. *Landscape Ecology* **12**: 117-125.

Wegner, J.F. and Merriam, G. (1979). Movements by birds and small mammals between a wood and adjoining farmland habitats. *Journal of Applied Ecology* **16**: 349-358.

Yahner, R. (1982b). Microhabitat use by small mammals in farmstead shelterbelts*.* *Journal of Mammalogy* **63**: 440-445.

Yahner, R.H. (1983a). Small mammals in farmstead shelterbelts: habitat correlates of seasonal abundance and community structure. *Journal of Wildlife Management* **47**: 74-84.

Further reading:

Bennett (1999), Best (1983), Dambach (1945), Eldridge (1971), Forman and Baudry (1984), Henderson *et al.* (1985), Ogilvie and Furman (1959), Pollard *et al.* (1974), Shalaway (1985), Swihart and Yahner (1982).

Reptiles and Amphibians

There has been little research on the ecology of reptiles and amphibians in revegetated habitats in agricultural landscapes. Pollard *et al.* (1974) provide an overview of knowledge of amphibians and reptiles in hedges in Britain. In comparison to other parts of the world, such as Australia, Britain has a species-poor herpetofauna. Nearly all of the common species have been recorded in hedges. In the United Kingdom, hedges are considered to provide food, shelter, breeding grounds and possibly movement pathways between habitats for vipers (Prestt 1971).

Factors identified as influencing herpetofaunal use of hedges include provision of suitable basking sites and hibernation burrows. Presence of leaf litter and provision of suitable habitat for prey items are also considered important.

Key references:

Pollard, E., Hooper, M.D. and Moore, N.W. (1974). Hedges. Collins: London.

Presst, I. (1971). An ecological study of the viper in southern Britain. *Journal of Zoology, London* **164**: 373-418.

Invertebrates

Hedgerows facilitate movements and provide habitat for many invertebrates (Pollard *et al.* 1974; Cameron *et al.* 1980; Lyngby and Nielsen 1981; Burel 1992; Thomas *et al.* 1992; Sparks and Parish 1995; Mineau and McLaughlin 1996; Paoletti *et al.* 1997) (see Table 5-1). Carabid beetles, for example, use hedgerows in France as resident habitat and may breed there, and some species disperse along them. Dispersion of carabids along hedgerows was found to vary with the ecology of species (e.g. 'core', 'peninsula' or 'corridor' species). Up to 100 m from forest, all carabid species were present in hedgerows but core woodland species did not extend further. Lanes, depending on their width and vegetation density may serve as stepping stones for forest carabid species. Abundance of forest carabid species in hedgerows was related to a dense herbaceous layer and presence of a tree layer (Burel 1989).

Invertebrate abundance and diversity is generally greater in hedgerows than in the surrounding fields. Factors influencing the use of hedgerows by invertebrates include the age of hedgerow, proximity to woodland remnants, vegetation cover and structure, floral species richness (butterflies), presence of grassy areas in the form of verges or ditch banks (butterflies), litter cover, and hedge management.

Key references:

Burel, F. (1989). Landscape structure effects on carabid beetles spatial patterns in western France. *Landscape Ecology* **2**: 215-226.

Burel, F. (1992). Effect of landscape structure and dynamics on species diversity in hedgerow networks. *Landscape Ecology* **6**: 161-174.

Gruttke, H. and Kornacker, P.M. (1995). The development of epigeic fauna in new hedges – a comparison of spatial and temporal trends. *Landscape and Urban Planning* **31**: 217-231.

Lewis, T. (1969). The diversity of the insect fauna in a hedgerow and neighbouring fields. *Journal of Applied Ecology* **6**: 453-458.

Lyngby, J.E. and Nielsen, H.B. (1981). The spatial distribution of carabids (Coleoptera, Carabidae) in relation to a shelterbelt. *Entomologiske Meddelelser* **48**: 133-140.

Mineau, P. and McLaughlin, A. (1996). Conservation of biodiversity within Canadian agricultural landscapes: integrating habitat for wildlife. *Journal of Agricultural and Environmental Ethics* **9**: 93-113.

Sparks, T.H. and Parish, T. (1995). Factors affecting the abundance of butterflies in field boundaries in Swavesey Fens, Cambridgeshire, UK. *Biological Conservation* **73**: 221-227.

Further reading:

Cameron *et al*. (1980), Lavorel (1988), Paoletti *et al.* (1997), Pollard *et al.* (1974), Sotherton *et al.* (1981), Thomas *et al.* (1992).

Summary

Studies of the use of planted or revegetated habitats by wildlife have been made in a range of countries around the world, but mainly relating to linear habitats such as hedgerows, shelterbelts and plantations. A wide range of species, especially birds, have been reported using these habitats, but there has been little critical analysis of their conservation value as a habitat compared with larger blocks of vegetation or nature reserves. Clearly, they provide shelter and foraging resources for many species, and have a role in increasing faunal diversity in cleared farm landscapes. However, many of the species that use them are 'edge' species, 'generalists' or 'open country' species rather than those of greatest conservation concern. It is likely that their greatest value lies in supplementing the area of existing habitats and increasing connectivity in fragmented rural landscapes.

6. Remnant vegetation and wildlife – lessons for revegetated habitats

In many parts of southern Australia, remnants of natural vegetation occur throughout cleared and developed environments as patches of various sizes and shapes or as linear strips along roads and streams. They share a number of similarities with revegetated habitats in that they are generally small in size, surrounded by other land uses, frequently isolated from other similar vegetation, and vary in the composition and management of their vegetation. Consequently, studies of the ecology of remnant vegetation and its use by different faunal groups may provide insights into the potential design and management of revegetated habitats and the values of revegetated blocks of different size, shape, composition and location.

Features of remnant vegetation

In situations where an important goal of revegetation is to re-establish natural plant communities or natural habitats for animal species, remnant vegetation can serve as a model. A number of features of remnant vegetation that have particular relevance to planning for revegetation are summarised below.

Variation in vegetation composition in relation to site characteristics
The composition of natural vegetation varies in relation to local features such as geological substrate, soil structure and nutrient levels, availability of moisture, and site aspect. This results in subtle variation in the relative composition of the plant community at a local scale, and changes in dominant plant species in relation to local environmental gradients (such as elevation or soil moisture).

Floristic diversity
Natural plant communities are generally composed of species representing a range of families and growth forms. Forest communities, for example, are likely to include trees, tall shrubs, low shrubs, ferns, grasses, sedges, herbs, creepers and mistletoes, as well as mosses, lichens, and fungi. This diversity of plant species in natural communities is integral to maintaining natural ecological processes and to the provision of resources used by animal species, especially for food.

Structural diversity
The structure of a natural plant community is influenced by the types of plant species present, the physical conditions of the site, and the relative growth stage of the community (e.g. regenerating, ecologically mature, recovering from recent disturbance). Aspects of structural diversity include the relative height of the vegetation, the number of vertical 'layers'of vegetation, the vegetative cover at different height intervals (or layers), the spatial heterogeneity (or patchiness) of dominant plants and vegetation cover, the size of individual plants (especially trees), and the amount of standing or fallen dead material. These structural characteristics have a critical influence on the availability of habitat components that animals use for shelter, refuge, movement, and breeding (e.g. Recher 1991).

Diversity in the soil and litter layer
The ground layer, including the soil and leaf litter, has an important but largely unrecognized role in natural communities. The enormous diversity of life in these layers, including fungi, bacteria, microarthropods and macroarthropods (many insects), has a key role in two essential processes. First, through their role in decomposition of dead organic material they are critical to the cycling of nutrients in ecosystems. Second, they form the foundation of detritus-based food chains responsible for much of the energy flow through terrestrial ecosystems. Soil and litter invertebrates are a food source for many animals in the food web.

Vulnerability to changes at edges
Remnant vegetation is particularly vulnerable to change at the interface between the vegetation and surrounding altered land (such as cleared farmland, urban development), and consequently vegetation edges differ from the 'interior' in a number of ways. Smaller remnants (such as those less than 10 ha in size) and narrow linear strips such as roadside and streamside vegetation are particularly vulnerable. In many

instances, the entire remnant may be influenced by 'edge effects'. Changes that frequently occur at the edges of remnant vegetation include (Saunders *et al*. 1991):

- changes in microclimate, such as increased solar radiation, increased exposure to wind, altered air and ground temperatures and changed humidity;
- modified hydrological regimes resulting from changes to soil moisture, changes in evapotranspiration and altered flows of water in surrounding land; and
- influx of nutrients, and plant and animal species from surrounding land uses.

All of these changes affect the composition and structure of the vegetation at, and near, edges and consequently the habitats for animal species. This, in turn, alters the composition of animal communities and may have far-reaching effects on ecological processes in the remnant vegetation.

Impacts of land use

Land use *within* remnant vegetation as well as *surrounding* the remnant has important effects on the quality of the habitat that it provides to plants and animals. Land uses such as sustained grazing by domestic stock can bring about marked changes to the soil structure, plant species composition, vegetative cover, and capacity for tree and shrub regeneration in remnant vegetation (Scougall *et al.* 1993). Changes to nutrient levels and the invasion of grasses and weeds can also result in profound change to the ground layer in remnants, and hence to habitats used by many invertebrates, reptiles, small mammals and ground-foraging birds.

Key references:

Hobbs, R. J. (1993b). Effects of landscape fragmentation on ecosystem processes in the Western Australian wheatbelt. *Biological Conservation* **64**: 193-201.

Hobbs, R. J. and Atkins, L.A. (1988). Effect of disturbance and nutrient addition on native and introduced annuals in plant communities in the Western Australian wheatbelt. *Australian Journal of Ecology* **13**: 171-179.

Loney, B. and Hobbs, R.J. (1991). Management of vegetation corridors: maintenance, rehabilitation and establishment. Pp 299-311 *in* Nature Conservation 2: The Role of Corridors. (Eds. D. A. Saunders and R. J. Hobbs). Surrey Beatty & Sons: Chipping Norton, New South Wales.

Recher, H.F. (1991). The conservation and management of eucalypt forest birds: resource requirements for nesting and foraging. Pp 25-34 *in* Conservation of Australia's Forest Fauna. (Ed. D. Lunney). Royal Zoological Society of New South Wales.

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

Scougall, S. A., Majer, J.D. and Hobbs, R.J. (1993). Edge effects in grazed and ungrazed Western Australian wheatbelt remnants in relation to ecosystem reconstruction. Pp 163-178 *in* Nature Conservation 3: The Reconstruction of Fragmented Ecosystems. (Eds. D. A. Saunders, R. J. Hobbs and P. R. Ehrlich). Surrey Beatty & Sons: Chipping Norton, New South Wales.

Faunal use of remnant vegetation

There have been many studies of the use of remnant vegetation by wildlife in Australia. These range from studies of single species (e.g. Suckling 1984; Saunders and Ingram 1987; Margules and Milkovits 1994) to studies of whole communities of different groups of animals (e.g. Bennett 1990a; Barrett *et al*. 1994; Smith *et al*. 1996). Some studies have included large areas such as national parks and other conservation reserves (Kitchener *et al*. 1980, 1982; Caughley and Gall 1985) while others have been concerned with small remnants amongst farmland (Howe *et al*. 1981; Fortin and Arnold 1997). There has also been a number of studies of the pattern of occurrence of various faunal groups in linear remnants, such as remnant roadside vegetation (e.g. Bennett 1988, 1991; Cale 1990; Arnold and Weeldenburg 1990; Keals and Majer 1991) and streamside vegetation (Hill 1995; Bentley and Catterall 1997).

These diverse studies have produced a wealth of information on the types of species that use remnant vegetation, the value of different types of remnants, and the effects of remnant size, shape, isolation and position. The following summaries highlight some of the main results derived from these studies. References for a range of source studies undertaken on birds, mammals, reptiles and invertebrates are listed below.

Species-area relationship
A highly significant relationship between the number of species present and the size of remnant vegetation has been consistently found in those studies in which sampling effort was proportional to remnant size (Figure 6-1). Larger remnants support a greater number of species of birds (Kitchener *et al.* 1982; Howe 1984; Loyn 1987), mammals (Kitchener *et al.* 1980; Suckling 1984; Bennett 1987) and reptiles (Kitchener and How 1982; Caughley and Gall 1985) than do smaller remnants. One of the reasons for this relationship is that larger remnants generally have a greater diversity of habitats than smaller remnants. Habitat diversity appears to be a particularly important influence on species richness of reptiles (e.g. Kitchener *et al.* 1980).

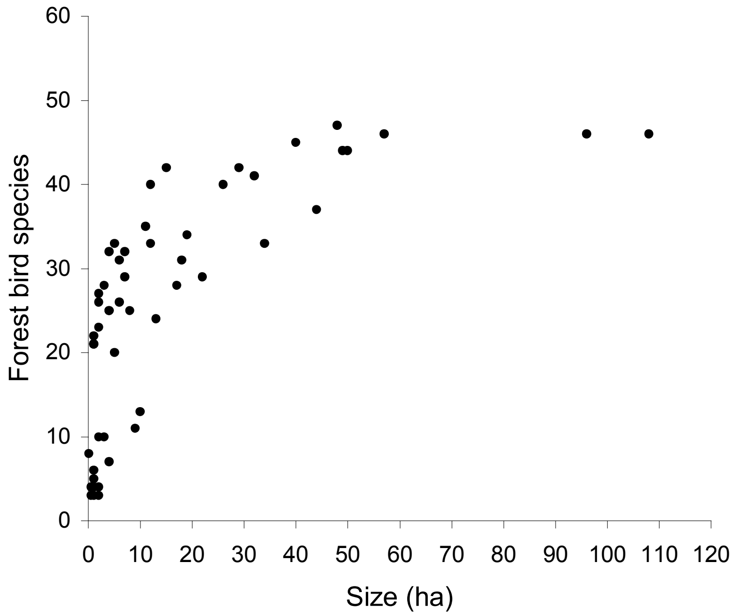

Figure 6-1. Species-area relationship for the number of forest bird species in forest remnants of varying sizes in Gippsland, Victoria (data from Loyn 1987).

Changes in species composition with remnant size
There are usually marked differences in the composition of the animal species present in remnants of different size classes. Larger remnants are more likely to support a faunal assemblage that is typical of the original unfragmented habitat, whereas faunal assemblages in small remnants are likely to be dominated by species that are able to persist in relatively disturbed habitats (Humphreys and Kitchener 1982). For some groups, such as mammals, there appears to be a relatively predictable pattern of occurrence of species in relation to remnant size with species 'dropping out' of the assemblage in successively smaller remnants (Bennett 1987; Deacon and Mac Nally 1998). It has proved difficult to reliably predict the kinds of species that are most vulnerable to habitat fragmentation, but a number of studies have provided insights for various groups (e.g. Laurance 1991; Saunders 1989; Sarré *et al*. 1995). Factors influencing vulnerability of species to fragmentation include:

- *body size*: larger species generally require larger areas of habitat in which to live (and in which to maintain a self-sustaining population) and so are less likely to occur in small fragments;
- *mobility*: species that are highly mobile and able to move between remnants are more likely to persist than those with limited capacity for movement; and
- *habitat specialisation*: species that require specialized habitats are likely to be more vulnerable to fragmentation than are species that have generalized habitat requirements.

Effect of spatial isolation
Remnants are isolated from similar vegetation by new forms of land use, such as cleared agricultural land or urban development. Those remnants in which animals are highly isolated from other populations, either by distance or by inhospitable surrounding habitats, are likely to be prone to species loss or change in the long

term (e.g. Arnold *et al*. 1993; Sarré *et al* 1995). Isolation reduces the ability of animals to move between remnants, and consequently restrict the opportunity for new individuals to supplement declining populations, for animals to recolonise should local extinctions occur, or to maintain ecological processes that involve animal movements.

Effect of time since isolation from similar vegetation
The numbers and types of species in remnant vegetation do not remain the same through time. Changes occur as some species disappear and new species colonize the habitat, often in relation to changes in surrounding land uses or disturbance processes in the vegetation (e.g. Saunders 1989; Recher and Serventy 1991). The trend is for a gradual long-term loss of species that are dependent on 'undisturbed habitat' and greater representation of species that are 'generalists' or favour disturbed habitats (including introduced species).

Quality of habitats in remnant vegetation
The way in which remnant vegetation is managed has a strong influence on the types of habitat resources available to animals. In turn, the availability and abundance of these resources has a significant impact on the occurrence and abundance of animal species, particularly for smaller and less-mobile species such as reptiles and invertebrates (e.g. Abensperg-Traun *et al*. 1996; Hadden and Westbrooke 1996; Smith *et al.* 1996; Bromham *et al*. 1999). Consequently, land uses such as grazing by stock and timber removal that result in changes to habitats (for example, loss of shrub and ground cover, soil compaction and disturbance, weed invasion, loss of large trees and associated tree hollows) may have greater effects on the occurrence of some species than factors such as remnant size or isolation (Abensperg-Traun *et al.* 1996; Deacon and Mac Nally 1998).

Values of linear remnants
In many regions of southern Australia, strips of remnant vegetation along roads and streams make up a substantial part of the remaining natural vegetation. A growing number of studies of these linear habitats (particularly roadside vegetation) show that they have value as remnant habitat for many species and that they enhance the connectivity of natural habitats in developed landscapes. Linear strips have been documented as a habitat for mammals (Bennett 1988, 1990a; Downes *et al.* 1997), birds (Arnold and Weeldenburg 1990; Cale 1990; Leach and Recher 1993; Bentley and Catterall 1996), reptiles (Brown and Bennett 1995) and some invertebrates (Keals and Majer 1991; Hill 1995).

In general, strips that are narrow and have experienced substantial degradation (such as grazing by stock or heavy weed infestation) are likely to be dominated by species that are common, habitat generalists, or that also occur in surrounding altered land. In contrast, wider and less-disturbed strips of remnant vegetation that retain key microhabitats, such as large trees, shrubs and ground cover and fallen timber, may be used by a large proportion of the fauna. They can have great value in their own right as a remnant habitat and support species that otherwise would not persist in the landscape (Bennett 1999).

Linear strips that connect two or more remnants have the potential to function as habitat corridors that assist the movement and interchange of species between otherwise-isolated populations. Such corridors may function by assisting the movement of single animals or by maintaining a resident population of animals along the corridor. Examples of the way in which remnant linear habitats enhance landscape connectivity and wildlife conservation are provided by Bennett (1990, 1999) and Saunders and Hobbs (1991).

Changes to ecological processes in remnants
Changes to ecological processes in remnant vegetation arise from the loss of native species, the introduction of new species (such as introduced predators or competitors), and changes to soil and vegetation from land use in the surrounding environment. To date our understanding of changes in natural ecological processes involving animals is limited, but it is likely that such changes have profound implications for the long-term conservation value of remnant vegetation (Saunders *et al.* 1991; Hobbs 1993b). Several examples of reported changes include:

- increased levels of predation on the native fauna by introduced predators (e.g. Red Fox *Vulpes vulpes*, Cat *Felis catus*);
- changes in levels of insect herbivory on plants (van Schagen *et al*. 1992);

- dominance of small remnants by Noisy Miners *Manorina melanocephala* with consequent aggressive exclusion of small insectivorous birds (Loyn 1987; Grey *et al*. 1997); and
- changes in relationships between mistletoes and host trees in woodland remnants (Norton *et al.* 1995).

Key references:

Birds

Arnold, G. W. and Weeldenburg, J.R. (1990). Factors determining the number and species of birds in road verges in the wheatbelt of Western Australia. *Biological Conservation* **53**: 295-315.

Barrett, G. W., Ford, H.A. and Recher, H.F. (1994). Conservation of woodland birds in a fragmented rural landscape. *Pacific Conservation Biology* **1**: 245-256.

Cale, P. (1990). The value of road reserves to the avifauna of the central wheatbelt of Western Australia. *Proceedings of the Ecological Society of Australia* **16**: 359-367.

Howe, R. W. (1984). Local dynamics of bird assemblages in small forest habitat islands in Australia and North America. *Ecology* **65**: 1585-1601.

Howe, R. W., Howe, T.D., and Ford, H.A. (1981). Bird distributions on small rainforest remnants in New South Wales. *Australian Wildlife Research* **8**: 637-651.

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

Loyn, R. H. (1987). Effects of patch area and habitat on bird abundances, species numbers and tree health in fragmented Victorian forests. Pp 65-77 *in* Nature Conservation: The Role of Remnants of Native Vegetation. (Eds. D. A. Saunders, G. W. Arnold, A. A. Burbidge and A. J. M. Hopkins). Surrey Beatty and Sons: Chipping Norton, New South Wales.

Lynch, J. F. and Saunders, D.A. (1991). Responses of bird species to habitat fragmentation in the wheatbelt of Western Australia: interiors, edges and corridors. Pp 143-158 *in* Nature Conservation 2: The Role of Corridors. (Eds. D. A. Saunders and R. J. Hobbs). Surrey Beatty and Sons: Chipping Norton, New South Wales.

Saunders, D. A. (1989). Changes in the avifauna of a region, district and remnant as a result of fragmentation of native vegetation: the wheatbelt of Western Australia. A case study. *Biological Conservation* **50**: 99-135.

Saunders, D. A. and de Rebeira, P. (1991). Values of corridors to avian populations in a fragmented landscape. Pp 221-240 *in* Nature Conservation 2: The Role of Corridors. (Eds. D. A. Saunders and R. J. Hobbs). Surrey Beatty and Sons: Chipping Norton, New South Wales.

Mammals

Arnold, G. W., Steven, D.E., Weeldenburg, J.R. and Smith, E.A. (1993). Influences of remnant size, spacing pattern and connectivity on population boundaries and demography in Euros *Macropus robustus* living in a fragmented landscape. *Biological Conservation* **64**: 219-230.

Bennett, A. F. (1987). Conservation of mammals within a fragmented forest environment: the contributions of insular biogeography and autecology. Pp 41-52 *in* Nature conservation: the role of remnants of native vegetation. (Eds. D. A. Saunders, G. W. Arnold, A. A. Burbidge and A. J. M. Hopkins). Surrey Beatty and Sons: Chipping Norton, New South Wales.

Bennett, A. F. (1990a). Land use, forest fragmentation and the mammalian fauna at Naringal, south-western Victoria. *Australian Wildlife Reserch* **17**: 325-347.

Downes, S. J., Handasyde, K.A., Elgar, M.A. (1997). The use of corridors by native mammals in fragmented eucalypt forest in north-eastern Victoria, Australia. *Conservation Biology* **11**: 718-726.

Kitchener, D. J., Chapman, A., Muir, B.G. and Palmer, M. (1980). The conservation value for mammals of reserves in the Western Australian wheatbelt. *Biological Conservation* **18**: 179-207.

Laurance, W. F. (1991). Ecological correlates of extinction proneness in Australian tropical rain forest mammals. *Conservation Biology* **5**.

Reptiles

Brown, G. and Bennett, A. (1995). Reptiles in Rural Environments: The Distribution, Habitat Requirements and Conservation Status of the Reptile Fauna of the Murray-Darling Basin Area in Victoria. A report to the Murray Darling Basin Commission. Department of Conservation and Natural Resources: Melbourne.

Caughley, J. and Gall, B. (1985). Relevance of zoogeographical transition to conservation of fauna: amphibians and reptiles in the south-western slopes of New South Wales. *Australian Zoologist* **21**: 513-529.

Hadden, S. A. and Westbrooke, M.E. (1996). Habitat relationships of the herpetofauna of remnant buloke woodlands of the Wimmera Plains, Victoria. *Wildlife Research* **23**: 363-372.

Kitchener, D. J., Chapman, A. Dell, J., Muir, B.G. and Palmer, M. (1980). Lizard assemblage and reserve size and structure in the Western Australian wheatbelt - some implications for conservation. *Biological Conservation* **18**: 179-207.

Kitchener, D. J. and How, R.A. (1982). Lizard species in small mainland habitat isolates and islands of south-western Western Australia. *Australian Wildlife Research* **9**: 357-363.

Sarré, S., Smith, G.T. and Myers, J.A. (1995). Persistence of two species of gecko (*Oedura reticulata* and *Gehyra variegata*) in remnant habitat. *Biological Conservation* **71**: 25-33.

Smith, G.T., Arnold, G.W., Sarre, S., Abensperg-Traun, M. and Steven, D. (1996). The effect of habitat fragmentation and livestock grazing on animal communities in remnants of gimlet *Eucalyptus salubris* woodland in the Western Australian wheatbelt. II Lizards. *Journal of Applied Ecology* **33**: 1302-1310.

Invertebrates

Abensperg-Traun, M., Smith, G.T., Arnold, G.W. and Steven, D. (1996). The effect of habitat fragmentation and livestock grazing on animal communities in remnants of gimlet *Eucalyptus salubris* woodland in the Western Australian wheatbelt. I. Arthropods. *Journal of Applied Ecology* **33**: 1281-1301.

Bromham, L., Cardillo, M., Bennett, A.F., and Elgar, M.A. (1999). Effects of stock clearing on the ground invertebrate fauna of woodland remnants. *Australian Journal of Ecology* **24**: 199-207.

Keals, N. and Majer, J.D. (1991). The conservation status of ant communities along the Wubin-Perenjori corridor. Pp 387-393 *in* Nature Conservation 2: The Role of Corridors. (Eds. D. A. Saunders and R. J. Hobbs). Surrey Beatty & Sons: Chipping Norton, New South Wales.

Margules, C. R. and Milkovits G.A. (1994). Contrasting effects of habitat fragmentation on the scorpion *Cercophonius squama* and an amphipod. *Ecology* **75**: 2033-2042.

Implications for the use of revegetated habitats by wildlife

Our present understanding of the ecology of remnant vegetation and its use by a range of faunal groups suggests that where the goal of revegetation is to mimic natural habitats for wildlife, planning and design need to be considered at several levels.

Site level

Important issues at the level of the individual 'site' include the need to select appropriate plant species to match the site characteristics, to plan for floristic and structural diversity of the revegetation, to consider the importance of developing ground-layer habitats, and to ensure that management is in place to deal with processes that might degrade the vegetation and habitat components. Time is a critical element in the quality of vegetation at the site level. It will take many years for newly-revegetated habitats to develop the characteristics of remnant vegetation, such as older trees with large canopies, large dead trees and large logs on the ground.

Block level

At the level of individual blocks of revegetation, important issues to consider include the size of the block, its shape and the length of edge, and its location in relation to surrounding land uses. Size is particularly important because habitat area is correlated with many other attributes such as population size, number of species, diversity of habitats, vulnerability to edge disturbance and so on. Increasing the area of revegetation is one of the most effective ways to increase its conservation value in the long term. Clearly, where the purpose of revegetation is to provide habitat for particular species, it is necessary to establish blocks of a size sufficient to meet that species' requirements.

Landscape level

A major issue at the landscape scale is the location of an area of revegetation in relation to other habitats, and how this will affect the capacity for animals to move to and from the new habitat. This is particularly important when the revegetation takes the form of linear strips (e.g. as shelterbelts or wildlife corridors). Additional issues at the landscape scale, when considering a broader conservation strategy, include the overall extent or amount of habitat and the representation of different vegetation types.

Summary

Where the primary goal of revegetation is to enhance biodiversity through the re-establishment of plant communities or animal habitats, useful insights can be gained from current knowledge of the ecology of remnant natural vegetation in rural landscapes. Characteristic features of the composition and structure of

remnant vegetation, and its vulnerability to disturbance from land use, can be used for planning for revegetation at the site level. Insights into important issues for revegetation at the block level come from studies of the use of remnant vegetation by wildlife species. These studies indicate the importance of size and shape, the maintenance of habitat components within blocks, and the location in relation to sources of disturbance. At a landscape level, studies of wildlife within remnant vegetation points to the importance of the location of the remnant in relation to other habitats, and thus the degree of isolation or habitat connectivity for populations of animals living within the remnant vegetation. These insights can be used in designing and planning revegetation to maximise its value as a habitat, either for single species or for broad faunal groups.

7. Benefits of revegetation and its role in sustainable land use

While revegetation has the potential to enhance the conservation of Australia's native flora and fauna, it also has significant benefits for sustainable land use including ameliorating land and waterway degradation, improving agricultural productivity, and enhancing human environments. This section outlines current knowledge of the benefits of revegetation and of how to design revegetation activities to achieve these benefits. An overview of the literature relating to revegetation techniques is presented in Section 8.

Protection of land and water resources

Revegetation has a role in overcoming land and waterway degradation, including minimising salinity and waterlogging, reducing erosion, landslips and mass movement of soil, and protecting water quality.

Salinity and waterlogging

Trees and other deep-rooted plants have the potential to minimise salinity problems resulting from rising saline groundwater. Through uptake of soil moisture and transpiration to the atmosphere, deep-rooted perennial vegetation distributed broadly across the landscape can reduce the amount of water added to the underlying water table and hence minimise or prevent its rise toward the surface. Measurements have been made of the rate at which trees take up and transpire water (Greenwood 1986; Schofield 1991; Williamson 1998), but the number of trees or percentage of a catchment that must be revegetated to stabilise or reduce the level of saline groundwater is a key area of research.

Research conducted in Western Australia provides an example of the extent to which revegetation (eucalypts in this instance) may assist with lowering water tables. Schofield *et al.* (1991) present a summary of the influence of revegetation on water table depth, particularly for revegetation of differing size, shape and location in the landscape. For example:

- *lower slope or discharge zone planting* was investigated at a farmland site where 44% of the natural vegetation had been cleared for agriculture. In 1979, 35% of the farmland was replanted with three species of eucalypts. Between 1979-1988 the water table beneath the revegetation fell by 2.0 m while the water table under pasture rose by 0.4 m.
- *strips or block style plantings*, which cover a smaller area of farmland (<15%), were also investigated at three sites. Tree planting had little or no effect on water tables, and it was suggested that in areas with annual rainfall greater than 700 mm, planting of less than 15% of farmland is unlikely to have a significant effect on the water table.
- *extensive high density plantings* covering more than 50% of farmland were investigated at two sites. At one site, 54% of an area cleared for agriculture was replanted with two eucalypt species. Between 1979-1988, the water table fell by 2.8 m, while under pasture there was a slight lowering (0.5 m) of the water table. At the second site about 70% of farmland was replanted, resulting in a lowering of the water table by 5.6 m under revegetation but a rise of 0.4 m under pasture, over the 1979-1988 period.

However, doubts have been raised about the effectiveness of water uptake by trees as a means of controlling problems of salinity and waterlogging at landscape and regional scales. For example, in a review of studies investigating groundwater uptake by plants, Thorburn (1996) found plants rarely take up more than 500 mm of saline groundwater (EC>5dS/m) per year, an amount similar to groundwater discharge rates from denuded soils. Furthermore, uptake of groundwater continually increases root zone salinity, further limiting water uptake by plants. Trials and simulations to test the role of different patterns of revegetation in controlling the water table are underway (see Land and Water Resources Research and Development Corporation 1999; Rural Industry Research & Development Corporation 1999 and CSIRO Australia 1999). Current knowledge suggests that changes in groundwater recharge over most of the landscape (e.g. tree planting across 50-70% of a catchment) are required to achieve significant reductions in the ultimate extent of salinity (T. Hatton, CSIRO, National Science Briefing June 1999, pers. comm. P. Lyons).

Nevertheless, selection of appropriate plant species and design of revegetation activities for ameliorating salinity and waterlogging have been widely addressed (see Riemer 1986; Oates and Clarke 1987; Morris and Jenken 1990; van der Moezel and Bell 1990 and other work cited within; Taylor 1994; Marcar *et al.* 1995; Oates 1995), but are not discussed further here.

Erosion

Vegetation can reduce water erosion of soils by:

- *intercepting rainfall:* Leaves intercept rainfall, absorbing much of the raindrop energy, thereby reducing the impact of rainfall splash which breaks down soil structure.
- *slowing water movement along the ground:* Extensive ground cover slows the downhill movement of water, regulates infiltration rates into the soil, and acts as a trap for silt and debris.
- *binding the soil:* The extensive, deep and spreading root systems of some plants bind the soil and improve its water absorption capacity. Movement of water deeper into the soil can be influenced by the presence of soil pores created by roots. Vegetation along stream banks reduces bank collapse by binding soils and slowing the flow of floodwater.

Wind erosion is reduced when vegetation slows the wind speed and reduces turbulence. Plantations of trees and shrubs can reduce wind speed over substantial distances , thus limiting the ability of wind to cause soil erosion. For example, shelterbelts can reduce wind speed by 50% in the zone up to 10 times their height (10H) and provide some shelter up to 30H (Haines and Burke 1993).

Vegetation can also assist with *preventing or controlling landslips and mass movement of soil.* The stability of the land surface is influenced by soil type, geology, soil moisture, slope and vegetation cover. Steep slopes in particular can be prone to mass movement of soil. Vegetation helps stabilise the soil by reducing soil water movement and maintaining groundwater levels. Roots and litter also bind soil particles together.

Design of revegetation and selection of plant species appropriate for controlling wind and water erosion have been addressed by Riemer (1986), Oates and Clarke (1987), Marshall (1990) and Harrison (1993), and are not discussed here.

Protecting and enhancing water quality and controlling stream bank erosion

Research into the role of vegetation in protecting water quality in Australia has been reviewed by Woodfull *et al.* (1993). Vegetation can protect aquatic environments in a number of ways:

- by acting as a filter for sediment and attached nutrients and contaminants (including bacteria);
- by providing shade and reducing fluctuations in water temperature and oxygen levels;
- by strengthening and stabilising banks, thereby helping to prevent erosion and subsequent silting of stream beds; and
- by providing terrestrial and stream habitat. Inputs of litter and other organic debris provide food for stream biota, and inputs of logs and other coarse debris provide habitat for invertebrates and fish.

Key references:

CSIRO Australia (1999). CSIRO Australia Home Page. Available URL: http//:www.csiro.au/index.html

Greenwood, E.A.N. (1986). Water use by trees and shrubs for lowering saline groundwater. *Reclamation and Revegetation Research* **5**: 423-434.

Land and Water Resources Research and Development Corporation (1999). LWRRDC Home Page. Available URL: http://www.lwrrdc.gov.au

Marcar, N., Crawford, D., Leppert, P., Jovanovic, T., Floyd, R. and Farrow, R. (1995). Trees for Saltland: A Guide to Selecting Native Species for Australia. CSIRO Press: Melbourne.

Morris, J.D. and Jenken, J.J. (1990). Trees in salinity control. Pp 357-366 *in* Trees for Rural Australia. (Ed. K.W. Cremer). Inkata Press: Melbourne.

Oates, N. (ed.) (1995). Putting Back the Bush: The Role of Trees in Sustainable Agriculture – Workbook 1. Greening Australia Ltd., Rural Industries Research and Development Corporation, and the Land and Water Research and Development Corporation: Canberra.

Rural Industries Research and Development Corporation (1999). RIRDC Home Page. Available URL: http//:www.rirdc.gov.au

Schofield, N.J., Bari, M.A., Bell, D.T., Boddington, W.J., George, R.J. and Pettit, N.E. (1991). The role of trees in land and stream salinity control in Western Australia. Pp Salinity 21-43 *in* The Role of Trees in Sustainable Agriculture: A National Conference. Proceedings. (Ed. R. Prinsley). Bureau of Rural Resources, Department of Primary Industries and Energy: Canberra.

Thorburn, P. (1996). Can shallow water tables be controlled by the revegetation of saline lands? *Australian Journal of Soil and Water Conservation* **9**(3): 45-50.

van der Moezel, P.G. and Bell, D.T. (1990). Saltland reclamation: selection of superior Australian tree genotypes for discharge sites. *Proceedings of the Ecological Society of Australia* **16**: 545-549.

Williamson, D.R. (1998). Land degradation processes and water quality effects: waterlogging and salinisation. Pp162-190 *in* Farming Action: Catchment Reaction – The Effect of Dryland Farming on the Natural Environment. (Ed. by J. Williams, R.A. Hook and H.L. Gascoigne). CSIRO Publishing: Melbourne.

Woodfull, J., Finlayson, B. and McMahon, T. (eds) (1993). The Role of Buffer Strips in the Management of Waterway Pollution from Diffuse Urban and Rural Sources. Proceedings of a workshop held 9 Oct 1992 at the University of Melbourne. Land and Water Resources Research and Development Corporation and University of Melbourne, Centre for Environmental Applied Hydrology. LWRRDC Occasional Paper No 01/93.

Further reading:

Cremer (1990b), Haines and Burke (1993), Harrison (1993), Marshall (1990), Oates and Clarke (1987), Riemer (1986), Schofield, (1991), Taylor (1994), van der Moezel *et al.* (1991).

Agricultural productivity

Agricultural production can benefit directly from revegetation through shade and shelter for livestock and crops, protection of buildings, and through harvesting of tree products such as timber and firewood. It has been estimated that up to 20% of a farm may be planted with trees without loss of economic return from the property (Taylor 1994; Bird and Cumming 1996).

Shelter and shade for livestock and crops

Environmental stress reduces livestock production and plant growth. Shelter from wind, sun or extreme temperatures improve livestock performance and increase plant growth. The benefit of planted shelterbelts has been extensively studied in Australia (see Reid and Bird 1990; Bird *et al.* 1992; Haines and Burke 1993; Burke and Wilson 1995), and in other countries (see Forman 1995).

Shelter provided by trees can directly benefit livestock production. Higher survival rates of newborn lambs, improved weaning rates, better weight gain by meat-producing animals, increased milk production and greater wool production have been reported as benefits of reducing the stress of harsh weather on livestock (King 1993). For example, Reid and Bird (1990) reported that at Armidale, NSW, shelter was found to almost halve the death rate of single lambs from 17% to 9%, increase wool production by 31%, and increase liveweight gain by over 10% at the highest stocking rate assessed over a 5 year period.

Shelter can also directly benefit pasture and crop production by reducing wind speed and turbulence, reducing wind erosion, lowering the rate of evaporation and thereby conserving soil moisture, moderating air and soil temperatures, and reducing the extent of physical damage to plants by windblown particles. Vegetation can also trap diseases attached to airborne particles and other windborne pests (Oates 1995; Abel *et al.* 1997). Crops grown near shelterbelts can have higher yields than crops grown in exposed paddocks (King 1993). For example, Reid and Bird (1990) reported that pasture or crop yield may average 20-30% more in a sheltered zone extending to a distance equal to 10 times the height of the shelterbelts than on unsheltered land. Research into citrus crops in NSW recorded a 37% increase in yield and improved size and appearance of fruit in response to artificial shelter.

Obtaining shade and shelter

The effect of shelterbelts on overall productivity depends on layout and design features (Reid and Bird 1990; Haines and Burke 1993; Bird and Cumming 1996; Burke and Wilson 1997; Abel *et al.* 1997). Shelter is influenced by:

- *height:* generally, a taller windbreak will give a greater extent of protection. Greatest protection (50% wind reduction) generally occurs to about 10H on the leeward side (although some shelter may occur up to 30H), and on windward side is limited to within 4H (Haines and Burke 1993).
- *orientation:* to be most effective, shelterbelts should be perpendicular to the most damaging winds.
- *permeability:* generally, semi-permeable barriers give useful shelter over a more extensive area than dense barriers. A porosity of 40-50% with small, evenly distributed gaps is best for maximising shelter (Haines and Burke 1993; Abel *et al.* 1997).
- *length:* generally, longer shelterbelts are more efficient than short belts. It has been suggested that shelterbelts should be at least 12 times longer than mature height (e.g. a 25 m tall belt should be at least 300 m long) (Reid and Bird 1990; Haines and Burke 1993; Bird and Cumming 1996). Linking a belt into existing shelter, woodlots or forests is another way of achieving shelter over as large an area as possible (Abel *et al.* 1997).
- *number of rows:* Shelterbelts with single rows are not widely advised because trees are more exposed and may fail to establish or reach maximum height Generally, most shelterbelts should have at least two and preferably 3-6 rows (Oates and Clarke 1987; Bird and Cumming 1996) for efficiency in providing shelter. For most applications 3-4 m spacing between rows is advocated (Burke *et al.* 1988; Bird and Cumming 1996).
- *plant spacing:* Spacing depends on a number of factors including species, number of rows, site characteristics, annual rainfall, and desired result. The aim of spacing is to allow trees and shrubs to provide the desired porosity and height. Generally, small shrubs and trees should be spaced 2.4-4 m (half their open crown width) while suggested spacing for trees ranges from 4-8 m apart (Oates and Clarke 1987; Haines and Burke 1993; Bird and Cumming 1996).

Placement of shelterbelts in relation to each other has implications for the wider landscape. For example, converting as little as 2% of a landscape to tree windbreaks (20 m tall spaced 25H apart) could achieve a 30% reduction in windspeed across the region (Bird and Cumming 1996; Abel *et al.* 1997). Spacing shelterbelts around 10-15H apart at maturity should achieve the most economic response in terms of pasture and animal production whilst greatly reducing soil erosion.

Advice on appropriate species for shelterbelts is widely available (Reid and Bird 1990; Haines and Burke 1993; Bird and Cumming 1996). A good belt should contain species which are fast growing (to provide early shelter), long lived, capable of regenerating after fire, tall (determines total distance of protection across paddock), able to retain foliage near the ground (to prevent wind gaps), and are local native species which are more likely to survive and grow.

Shelterbelts have the potential to serve purposes other than shelter, two of which are improving the attractiveness of rural landscapes and conservation of flora and fauna. Consequently, consideration should be given to species selection and design of plantings to achieve multiple goals.

Agroforestry and other tree products

Revegetation has the potential to provide a range of other long-term economic benefits on farms.

Agroforestry and other commercial timber products: Agroforestry and farm forestry are terms often used interchangeably to describe the incorporation of commercial tree growing into farming systems (Robins *et al.* 1996). Trees planted may be harvested for timber products including firewood, fenceposts, furniture or building timber, and pulpwood. Design of plantations and species selection depends on the initial capital available, the desired product and financial return, and any simultaneous benefits to be achieved (Cremer 1990a). For example, a product such as pulpwood has a low value to weight ratio (about $20/t) and requires large plantations (minimum 10 ha) to be economically viable. In comparison, high value sawlogs fetch over $50/t and thereby require a smaller planted area for equivalent returns (Abel *et al.* 1997).

Timber products for private use: Planted trees can ultimately be used for firewood or fenceposts on-site, thereby supplementing maintenance expenditures.

Fodder: Native vegetation can provide a substitute fodder source for livestock. Tree species suitable for fodder have been investigated (see Oates and Clarke 1987; Cremer 1990b; Reid 1995).

Other tree products: Native vegetation can also provide products for sale or farm use such as firewood, tree seed, honey, flowers and branchlets/foliage for floral arrangements, and essential oils (e.g. *Eucalyptus*) (Reid and Bird 1990).

Design of plantings has been addressed for farm timber production (Riemer 1986; Campbell *et al.* 1990; Hall 1990) and agroforestry (Reid and Wilson 1986; Oates and Clarke 1987; Cremer 1990a; Race 1993; Bird and Cumming 1996; Abel *et al.* 1997), and is not discussed here. Likewise, information on species selection is available for:

- fuel and firewood (Doran and Turnbull 1986; Oates and Clarke 1987; Cremer 1990b);
- timber production (Oates and Clarke 1987; Cremer 1990b; Taylor 1994);
- fenceposts (Cremer 1990b);
- agroforestry (Reid and Wilson 1986; Doran and Turnbull 1986); and
- nut trees and other crops (Oates and Clarke 1987).

Other reported benefits of revegetation for farm productivity

Protection of buildings: The value of revegetation (shelterbelts in particular), for protecting buildings has been addressed by several authors (DAHE 1986; Riemer 1986; Oates and Clarke 1987; Reid and Bird 1990; Abel *et al.* 1997). Native vegetation can:

- provide shelter and shade and therefore protection from buffeting and sandblasting, and reduce the need for heating and cooling. Buildings and yards should be placed 3-6H from shelterbelts to maximise protection from wind (Reid and Bird 1990).
- provide fire protection. By reducing windspeed and breaking up the fire front, a shelterbelt will help control the spread of a grass fire. Even a fairly open belt achieving a 50% reduction in windspeed will reduce the rate of advance of a fire front to 33% of that on open grassland (DAHE 1986). Vegetation can also shield buildings from radiant heat. Designing plantings and selecting species for fire protection has been addressed by DAHE (1986); Riemer (1986); and Oates and Clarke (1987).

Honey production: Pollen and nectar are a food source for bees. Bees play an important role in pollination and therefore maintaining crop and pasture production. However, honey bees may also compete with native bees, birds and mammals for nectar and tree hollows. Tree species best suited for honey production have been addressed by Oates and Clarke (1987) and Cremer (1990b).

Reduce evaporation of free water: Planting trees around farm dams can reduce evaporation by reducing wind flow across the water surface (Reid and Bird 1990).

Key references:

Abel, N., J. Baxter, J., Campbell, A., Cleugh, H., Fargher, J., Lambeck, R., Prinsley, R., Prosser, M., Reid, R., Revell, G., Schmidt, C., Stirzaker, R. and Thorburn, P. (1997). Design Principles for Farm Forestry: A Guide to Assist Farmers to Decide Where to Place Trees and Farm Plantations on Farms. Canberra, Rural Industries Research and Development Corporation.

Bird, R. and Cumming, K. (1996). Establishment and management of trees for shelter, conservation and agroforestry. Pp 37-62 *in* From the Ground Up – Property Management Planning Manual. (Ed. P. Dixon). Department of Conservation and Natural Resources and Department of Agriculture: Melbourne.

Burke, S. and Wilson, A. (ed) (1995). A Haven from Storm and Drought: The Role of Trees in Sustainable Agriculture – Workbook 3. Greening Australia Ltd., Rural Industries Research and Development Corporation, and the Land and Water Research and Development Corporation: Canberra.

Cremer, K.W. (ed.) (1990a). Trees for Rural Australia. Inkata Press: Melbourne.

Department of Arts, Heritage and Environment (1985). Think Trees, Grow Trees. Australian Government Publishing Service: Canberra.

Oates, N. (ed.) (1995). Putting Back the Bush: The Role of Trees in Sustainable Agriculture – Workbook 1. Greening Australia Ltd., Rural Industries Research and Development Corporation, and the Land and Water Research and Development Corporation: Canberra.

Race, D. (ed.) (1993). Agroforestry: Trees for Productive Farming. Agmedia: East Melbourne.

Reid, R. (ed) (1995). Making Farm Trees Pay: The Role of Trees in Sustainable Agriculture – Workbook 2. Greening Australia Ltd., Rural Industries Research and Development Corporation, and the Land and Water Research and Development Corporation: Canberra.

Further reading:

Bird *et al.* (1992), Burke *et al.* (1988), Campbell *et al.* (1990), Cremer (1990b), Doran and Turnbull (1997), Forman (1995), Haines and Burke (1993), King (1993), Oates and Clarke (1987), Reid and Bird (1990), Reid and Wilson (1986), Riemer (1986), Roberts (1992), Robins *et al.* (1996), Taylor (1994).

Addressing climate change and the Greenhouse effect

By absorbing carbon dioxide through the process of photosynthesis, and storing carbon in plant biomass, vegetation plays an important role in ameliorating the impacts of greenhouse gas accumulation in the atmosphere. Native forests and woodlands store immense quantities of carbon in above- and below-ground biomass. However, when vegetation is cleared and left to decay or burn, the stored carbon is released back into the atmosphere.

Vegetation management, particularly revegetation, is likely to play a key role in Australia's ability to meet its commitments to limit greenhouse gas emissions (Commonwealth of Australia 1998a). In 1998, amid increasing scientific and community concerns regarding global climate change, the Australian Government signed the Kyoto Protocol committing Australia to limit greenhouse gas emissions to 8% above the 1990 level. The National Greenhouse Strategy (1998) sets out a range of measures to reduce greenhouse gas emissions and establishes a framework for meeting agreed greenhouse gas reduction targets (Commonwealth of Australia 1998a).

Australia is well placed to offset much of its industry-generated emissions of greenhouse gases through the revegetation of cleared land. By acting as sinks for atmospheric carbon dioxide, vegetation, particularly woody plants, may be able to offset the emissions of carbon dioxide elsewhere. Key government initiatives (Commonwealth of Australia 1998a) which aim to substantially increase the rates of revegetation and thereby contribute to greenhouse emission targets include:

- the *Bushcare Program (National Vegetation Initiative)* under the Federal Government's Natural Heritage Trust is investing $348 million into the management and establishment of native vegetation across Australia. The aim of the program is to reverse the long-term decline in the quality and extent of native vegetation communities across Australia.
- the *Farm Forestry Program* will invest a total of $58 million to encourage investment in commercial farm forestry with the aim of increasing farm viability and sustainable land use.
- the *Plantations for Australia: The 2020 Vision Strategy* is aimed primarily at increasing investment in farm forestry on private land. Under the strategy, an average of 80,000 ha of plantations per year will be established, with the goal of 3 million ha of plantations established by the year 2020.
- *Bush for Greenhouse* will assist industry, the community and government to develop carbon sinks through revegetation and to move towards an emissions trading framework.

There is considerable interest from industry and governments to develop a process whereby the carbon sequestered by vegetation can be traded and used to off-set the impacts of carbon emitted by industry (Commonwealth of Australia 1998b). Carbon sinks and other greenhouse-motivated programs represent relatively new sources for investment in revegetation and the retention of native vegetation. These programs may offer substantial opportunities to meet both Australia's international greenhouse obligations and contribute to sustainable land management and the conservation of biodiversity.

Key references:

Commonwealth of Australia (1998a). The National Greenhouse Strategy – Strategic Framework for Advancing Australia's Greenhouse Response. Australian Greenhouse Office: Canberra.

Commonwealth of Australia (1998b). Greenhouse Challenge Vegetation Sinks Workbook – Quantifying Carbon Sequestration in Vegetation Management Projects. Australian Greenhouse Office: Canberra.

Australian Greenhouse Office (1998). Australian Greenhouse Office Home Page. Available URL: http://www.greenhouse.gov.au.

Enhancing the amenity of human environments

Trees and shrubs enhance the scenic beauty of landscapes (DAHE 1986) and create a more pleasant environment by providing shelter and shade. In so doing, natural vegetation can enhance property values (DAHE 1986; Reid and Bird 1990; Cook and Cable 1995). For example:

> *"Retained trees and shrubs beautify the landscape and increase amenity and property resale value. Experience in Victoria indicates that a property with good shelterbelts and treed areas often has a 10 to 30 percent higher price than a treeless property in the same district" (Johnston and Williams 1993).*

Extensive revegetation with trees and shrubs along major highways has an important amenity role, including enhancing the visual environment for drivers and shielding lights from oncoming vehicles (for double-laned highways). Revegetation in urban open spaces often has multiple goals, including an improved recreational and aesthetic environment for humans.

Designing plantings and species selection for aesthetics have been addressed by a number of authors, including Campbell *et al.* (1990), Chapman (1990), Cremer (1990b), and Reid and Bird (1990). Species should be selected to fit the character of the area while avoiding extensive use of a single species (Reid and Bird 1990)

Key references:

Campbell, R., Chandler, R. and Thomas, G. (1990). Victoria Felix: Improving Rural Land with Trees. Department of Conservation and Environment and Graduate School of Environmental Science, Monash University: Melbourne.

Chapman, M. (1990). Amenity. Pp 336-356 *in* Trees for Rural Australia. (Ed. K.W. Cremer). Inkata Press: Melbourne.

Cook, P.S. and Cable, T.T. (1995). The scenic beauty of shelterbelts on the Great Plains. *Landscape and Urban Planning* 32: 63-69.

Department of Arts, Heritage and Environment (1985). Think Trees, Grow Trees. Australian Government Publishing Service: Canberra.

Johnston, P.J.M. and Williams, R.D. (1993). Management of native vegetation for timber, land protection and conservation. *In* The Role of Trees in Sustainable Agriculture – A National Conference. Kluwer Academic Publishers: Netherlands.

Reid, R. and Bird, P.R. (1990). Shade and shelter. Pp 319-335 *in* Trees for Rural Australia. (Ed. K.W. Cremer). Inkata Press: Melbourne.

Further reading:

Baer (1989), Cremer (1990b), Oates (1995).

Benefits of conserving wildlife

In addition to the potential for increasing habitat and therefore population sizes of wildlife in rural environments through revegetation, many authors have pointed to the benefits that may accrue from having healthy wildlife populations in the environment (Breckwoldt 1983; DAHE 1986; Burke *et al.* 1988; Davidson and Davidson 1992; Johnston and Don 1995; Ford undated). Three main types of benefits have been noted: the role of native animals as predators of species that may potentially become agricultural pests; the role of native animals in maintaining the natural function of ecosystems; and the contribution of native animals to the quality of life for people.

Native animals as predators of potential agricultural pests

High levels of mortality are required for many species, especially invertebrates, simply to maintain populations at stable levels. Davidson and Davidson (1992) estimate, for example, that annual mortality of 99.9% is required to maintain the population size of the Black Field Cricket *Teleogryllus commodus*. They suggested that if annual mortality fell to 99.8%, the population would double in size! This species occasionally increases to plague numbers in some areas and is recognised as an agricultural pest.

Regulation of population numbers of invertebrate pest species results from mortality from climatic conditions, disease and predation. While the relative importance of predation is generally not known, it clearly does have a role in regulating population numbers. Examples of the role of native wildlife as predators include the following:

- Australian Magpies *Gymnorhina tibicens* consume large numbers of scarab larvae from pastures (Ford undated; Johnston and Don 1995);
- ibis eat large quantities of crickets, grasshoppers and beetle larvae in pastures. It was estimated that birds at a single ibis rookery in Victoria consumed about 500 t of food per day (DAHE 1986);
- some native wasp species parasitise scarab larvae, and a small scelionid wasp parasitises locust eggs, with recorded levels of parasitism above 90% at some egg bed sites (Davidson and Davidson 1992);
- Sugar Gliders *Petaurus breviceps* inhabiting remnant forest vegetation in south Gippsland, Victoria, were estimated to consume 3.24 kg of insects per glider per year. Many of the insect species consumed by the gliders (e.g. Christmas Beetles, Family Scarabeidae) have been implicated in pasture damage and eucalypt dieback (Breckwoldt 1983).

Role of native animals in maintaining ecosystem function

Native animals are integral to maintaining the function of natural ecosystems in rural environments. They are involved in many ecosystem processes, such as the regulation and dispersal of plant parasites (e.g. mistletoes), the pollination of plants, the dispersal of seeds and fruits, nutrient cycling, and predator-prey relationships.

For example, 'dieback' of rural trees is of concern and is recognised to be a complex process (Landsberg *et al.* 1990). It is evident that native wildlife play a part in maintaining healthy woodland ecosystems. It has been estimated that in healthy eucalypt woodland, birds may take about half of the insects produced (around 30 kg per ha per year), and small mammals (Sugar Gliders, bats etc.), predatory insects and spiders take a substantial proportion of the rest. Woodland suffering severe defoliation and dieback (from insect attack) had only 10% of the birds of healthy woodland (Ford and Bell 1981).

Quality of life

The presence of wildlife in the environment adds greatly to the quality of life for many people. The sounds of Laughing Kookaburras *Dacelo novaeguineae*, the caroling of Australian Magpies *Gymnorhina tibicen* in the morning, the calls of honeyeaters in a flowering tree, and the cacophony of frogs calling from swampland on a warm evening are part of the background, often taken for granted in rural environments. Similarly, the sight of Flame Robins *Petroica phoenicea* on a farm fence, a glimpse of Platypus *Ornithorhynchus anatinus* in a creek, a Bearded Dragon *Pogona barbata* basking on a fence post, or the flash of pink and grey as a flock of Galahs *Eolophus roseicapilla* wheel across the sky at sunset, are part of the rich tapestry of rural Australia.

These sights and sounds are difficult to value in economic terms, and are are seldom noticed until they are lost. Nevertheless they have deep emotional value for many people and form a distinctive part of the Australian rural image.

Designing revegetation for wildlife

Planning and designing revegetation for nature conservation has been addressed by a number of authors, frequently as a short section within a broader discussion of revegetation (Breckwoldt 1983; DAHE 1986;

Riemer 1986; Oates and Clarke 1987; Cremer 1990a; Davidson and Davidson 1992; Race 1993; Johnston and Don 1995; Oates 1995; Bennett and Platt 1996; Mineau and McLaughlin 1996). However, such advice is based on a general understanding of wildlife habitat requirements, rather than on known use of revegetation by wildlife.

The main factors to consider in planning revegetation for wildlife have been identified as the diversity of trees, shrubs and other plants, the types of species of plants used, the structural diversity of the habitat, and the location of revegetation to provide corridors linking with larger habitat areas. The retention of dead trees with hollows has been noted as important as nesting sites for many species of wildlife (Burke *et al.* 1988). Use of locally indigenous species is widely advocated (Riemer 1986; Race 1993) and species selection for wildlife habitat has been addressed by Oates and Clarke (1987), Cremer (1990a); Nadolny (1991) and Stelling (1994).

These factors primarily relate to the type and quality of vegetation at a particular site and the resources they provide to animals for food, shelter, refuge and breeding. These are important, but studies of the use of remnant natural vegetation by wildlife (Section 6) show that other attributes such as the size and shape of habitats, their context in the landscape, and the regional configuration and representation of habitats are also important. These issues are now beginning to be addressed in relation to landscape restoration in rural environments (Hobbs and Yates in press; McIntyre and Hobbs in press; Lambeck 1999).
Principles to enhance the value of revegetation as habitat for wildlife are further developed in the companion publication to this report (Bennett *et al.* 1999). They are based on understanding the requirements of wildlife at several spatial scales.

Key references:

Bennett, A. and Platt, S. (1996). Wildlife on the farm. Pp 23-36 *in* From the Ground Up – Property Management Planning Manual. (Ed. P. Dixon). Department of Conservation and Natural Resources and Department of Agriculture: Melbourne.

Bennett, A.F., Kimber, S.L. and Ryan, P.A. (1999). Revegetation and Wildlife: Enhancing Revegetated Habitats for Wildlife Conservation in Rural Environments. Report to Environment Australia: Canberra.

Breckwoldt, R. (1983). Wildlife in the Home Paddock: Nature Conservation for Australian Farmers. Angus and Robertson Publishers: Melbourne.

Cremer, K.W. (ed.) (1990a). Trees for Rural Australia. Inkata Press: Melbourne.

Davidson, R. and Davidson, S. (1992). Bushland on Farms: Do You Have a Choice? Australian Government Publishing Service: Canberra.

Department of Arts, Heritage and Environment (1985). Think Trees, Grow Trees. Australian Government Publishing Service: Canberra.

Fleury, A.M. and Brown, R.D. (1997). A framework for the design of wildlife conservation corridors: with specific application to southwestern Ontario. *Landscape and Urban Planning* 37: 163-186.

Ford (undated). Farm Birds: Nature's Pest Controllers. Pamphlet. Department of Arts, Heritage and Environment: Canberra.

Hobbs, R.J. and Yates, C.J. (in press). Priorities for action and management guidelines. *In* Temperate Eucalypt Woodlands in Australia: Biology, Conservation, Management and Restoration. (Eds. R.J. Hobbs and C.J. Yates). Surrey Beatty and Sons: Chipping Norton, New South Wales.

Johnston, P. and Don, A. (1995). Grow Your Own Wildlife: How to Improve Your Local Environment. Greening Australia Limited: Canberra.

Lambeck, R.J. (1999). Landscape Planning for Biodiversity Conservation in Agricultural Regions: A Case Study from the Wheatbelt of Western Australia. Biodiversity Technical Paper No. 2. Department of the Environment and Heritage: Canberra.

Landsberg, J., Morse, J. and Khanna, P. (1990). Tree dieback and insect dynamics in remnants of native woodlands on farms. *Proceedings of the Ecological Society of Australia* **16**: 149-165.

McIntyre, S. and Hobbs, R. (in press). Human impacts on landscapes: matrix condition and management priorities. *In* Nature Conservation 5: Nature Conservation in Production Landscapes. (Eds. J. Craig, N. Mitchell and D.A. Saunders). Surrey Beatty and Sons: Chipping Norton, New South Wales.

Oates, N. (ed.) (1995). Putting Back the Bush: The Role of Trees in Sustainable Agriculture – Workbook 1. Greening Australia Ltd., Rural Industries Research and Development Corporation, and the Land and Water Research and Development Corporation: Canberra.

Further reading:

Best *et al.* (1995), Burke *et al.* (1988), Capel (1988), Chapman (1990), Emmerich and Vohs (1982), Ford and Bell 1981; Johnson and Beck (1988), Johnson *et al.* (1994), Mineau and McLaughlin (1996), Nadolny (1991), Oates and Clarke (1987), Race (1993), Riemer (1986), Stelling (1994).

Summary

Revegetation in rural environments offers a number of benefits for sustainable land management and agricultural productivity. Revegetation can be used to reduce land and water degradation by strategic re-establishment of vegetation to minimise the rise of saline groundwater, to reduce waterlogging of soils, to reduce erosion and to protect water quality. These measures, together with planting of vegetation as shade and shelter for stock and crops, have the potential to enhance agricultural productivity on farms. Revegetation in the form of agroforestry also has potential to provide economic benefits through timber products such as firewood, pulpwood and building timbers. By storing carbon in plant biomass, revegetation provides an opportunity to slow the rate of increase of greenhouse gases in Australia, such as CO_2*, that contribute to global warming. Maintaining healthy wildlife populations in rural environments has numerous benefits, including enhancing the quality of life and maintaining ecosystem processes such as pollination, nutrient cycling and regulation of pest populations.*

8. Planning revegetation projects

Planning for revegetation involves identifying the problems to be addressed, the size and location of planting needed to achieve the objectives, the plant species to be used (especially those from the local area), how to grow and establish plants, and knowing where to go for advice for a particular area.

Revegetation techniques depend on the purpose of planting and ultimately are influenced by individual site characteristics including topography, soils, climate, local flora and fauna, and degree of environmental problems. Local knowledge is essential. In view of this, revegetation techniques are not discussed in detail in this section, rather, a general outline of planning considerations and a broad overview of techniques is provided, with reference to literature where further information can be found.

Planning

Planning is vital to the success of any tree planting program, as is a clear understanding of its purpose (Oates and Clarke 1987; Abel *et al*. 1997). Planning for revegetation occurs at several levels. It is incorporated in regional vegetation plans, catchment management plans, urban greening plans and farm plans (either groups of farmers planning co-operatively or independently). The planning process undertaken at the local scale can be used to illustrate considerations for other revegetation programs.

Property management or 'whole farm' planning is a widely advocated process that assists farmers to identify existing and potential problems on a property, and to develop a long-term plan to tackle land degradation and farm productivity on a whole farm basis. Revegetation forms a major component of farm plans because it can integrate the goals of reducing land degradation, improving farm productivity and assisting nature conservation. Planning for nature conservation as part of this process requires an assessment of the natural resources of the farm and development of appropriate management strategies for the future. Several guides that have been developed to assist property assessments to incorporate nature conservation goals are the Save the Bush Toolkit (Charles Sturt University), Property Management Planning Manual (Dixon 1996) and Design Principles for Agroforestry (Abel *et al*. 1997).

A number of features to be considered when planning revegetation for nature conservation purposes have been identified. These include:

- *existing vegetation*: Remnants of former natural vegetation can be used as a guide for planning which species to plant, and the amount and quality of existing vegetation can also influence where to direct revegetation efforts. Protection of existing natural vegetation should generally have priority over establishment of new vegetation;
- *previous vegetation*: The distribution of broad vegetation types and of individual plant species can indicate those species suited to a particular area or the most appropriate species to replace in the landscape;
- *climate, soil type and landscape characteristics*: These environmental conditions will influence the type of vegetation which can be re-established;
- *existing fauna*: Type of species present that may benefit from revegetation; and
- *previous fauna*: The distributional patterns of animal species can indicate the types of species that may potentially return to an area, and those that can be targeted when designing revegetation efforts.

Assistance with assessing properties and in developing a farm plan is available from a number of sources:

- examples of successful farm plans, such as those outlined by Riemer (1986), Garrett (1989), Campbell (1991), Davidson and Davidson (1992) and Dixon (1996);
- guides for assessing a property and developing a farm plan such as that by Dixon (1996), and as outlined in the Save the Bush Toolkit (Charles Sturt University 1997). Suggestions are also made by Oates and Clarke (1987), Garrett (1989), Campbell (1991), Hirst and Morton (1993), Saunders and Hobbs (1995) and Abel *et al*. (1997);

- guides to flora and fauna, that will assist in identifying species, their distributions and ecological requirements (e.g. Costermans 1992; Fuhrer 1993; Cogger 1994; Barker *et al.* 1995; Strahan 1995; Zborowski and Storey 1995; Brunet 1996; Simpson and Day 1996; Triggs 1996);
- flora and fauna surveys of local areas conducted by government conservation departments, or field naturalists and conservation groups;
- demonstration farms, field days and short courses (e.g. those run by Greening Australia); and
- professional advice which is available from local offices of government conservation departments, Greening Australia, Landcare co-ordinators, Bushcare facilitators, and other farmers.

Design

Regardless of the type of farming practice or geographic location of the property, farm plans generally involve planting combinations of linear strips and blocks across the landscape to ameliorate particular problems. Potential benefits of vegetation on farms are discussed in Section 7. Achieving these benefits depends on the design of the revegetation.

Design considerations for revegetation vary according to the purpose and planting regime. Design features that have been recommended include: the orientation and location in the landscape; the height, width, length and shape of plantings; the density of vegetation; tree spacing; the permeability of shelterbelts; number of rows in shelterbelts; the types of plants (species); and fencing and other maintenance (Breckwoldt 1983; Riemer 1986; Oates and Clarke 1987; Campbell *et al.* 1990; Cremer 1990a; Race 1993; Stelling 1994; Burke and Wilson 1995; Oates 1995; Saunders and Hobbs 1995; Bird and Cumming 1996; Abel *et al.* 1997)

Species selection

Species selection for revegetation has been addressed in numerous publications (Reid and Wilson 1986; Oates and Clarke 1987; Venning 1988; Simpfendorfer 1989; Campbell *et al.* 1990; Cremer 1990a; van der Moezell and Bell 1990; Lefroy *et al.* 1991; Nadolny 1991; van der Moezell *et al.* 1991; Race 1993; Stelling 1994; Taylor 1994; Burke and Wilson 1995; Marcar *et al.* 1995; Abel *et al.* 1997; Doran and Turnbull 1997). When choosing species to plant, the most important criterion is the purpose of the plantings. Suitability of species for these purposes, and therefore choice of species, also depends on their ability to cope with local conditions including soil types, climate, landform and aspect, and environmental conditions (e.g. salinity or waterlogging) (Campbell 1991). Advice on species for a particular purpose or area should be sought from local sources.

The use of local species is emphasised because they are generally of greater value for wildlife, they harmonise with and retain natural landscape and environment values, and are usually adapted to local conditions (Cremer 1990b; Nadolny 1991). However, for timber production or fodder, for example, local species are often unsuitable and other natives or exotics are used (Lefroy *et al.* 1991; Nadolny 1991).

Techniques

Revegetation is achieved by three main techniques: by planting trees and shrubs as open-rooted or tube stock, by direct seeding, or by allowing areas to regenerate naturally. There is an abundance of literature available on revegetation techniques, ranging from site preparation through to establishing and caring for plants (e.g. Oates and Clarke 1987; Venning 1988; Burke 1990; Cremer 1990a; Lefroy *et al.* 1991; Doran and Turnbull 1997). However, these techniques are constantly being revised and improved as experience is gained, and therefore local advice should be sought to obtain the most current information for a certain area. No attempt is made here to review techniques.

Monitoring of planted trees is essential in order to determine the effectiveness of a given technique in a particular area, and to learn from and adapt techniques for the future. Monitoring is also essential to determine whether the objectives of the revegetation have been achieved. This may require a long-term commitment because achieving objectives such as reduction in water tables and provision of wildlife habitat may take many years. Monitoring is an important, but frequently neglected aspect of revegetation.

Key references:

Abel, N., J. Baxter, J., Campbell, A., Cleugh, H., Fargher, J., Lambeck, R., Prinsley, R., Prosser, M., Reid, R., Revell, G., Schmidt, C., Stirzaker, R. and Thorburn, P. (1997). Design Principles for Farm Forestry: A Guide to Assist Farmers to Decide Where to Place Trees and Farm Plantations on Farms. Canberra, Rural Industries Research and Development Corporation.

Burke, S. and Wilson, A. (ed) (1995). A Haven from Storm and Drought: The Role of Trees in Sustainable Agriculture – Workbook 3. Greening Australia Ltd., Rural Industries Research and Development Corporation, and the Land and Water Research and Development Corporation: Canberra.

Campbell, A. (1991). Planning for Sustainable Farming: The Potter Farmland Plan Story. Lothian Publishing: Melbourne.

Charles Sturt University and Orange Agricultural College, University of Sydney (1997). Save the Bush Toolkit. Charles Sturt University Printery: Bathurst, New South Wales.

Cremer, K.W. (ed.) (1990a). Trees for Rural Australia. Inkata Press: Melbourne.

Davidson, R. and Davidson, S. (1992). Bushland on Farms: Do You Have a Choice? Australian Government Publishing Services: Canberra.

Dixon, P. (ed.) (1996). >From the Ground Up – Property Management Planning Manual. Department of Conservation and Natural Resources and Department of Agriculture: Melbourne.

Doran, J.C. and Turnbull, J.W. (eds.) (1997). Australian Trees and Shrubs: Species for Land Rehabilitation and Farm Planting in the Tropics. Australian Centre for International Agricultural Research: Canberra.

Lefroy, E.C., Hobbs, R.J. and Atkins, L.J. (1991). Revegetation Guide to the Central Wheatbelt. Department of Agriculture Western Australia: Perth.

Marcar, N., Crawford, D., Leppert, P., Jovanovic, T., Floyd, R. and Farrow, R. (1995). Trees for Saltland: A Guide to Selecting Native Species for Australia. CSIRO Publishing: Melbourne.

Oates, N. (ed.) (1995). Putting Back the Bush: The Role of Trees in Sustainable Agriculture – Workbook 1. Greening Australia Ltd., Rural Industries Research and Development Corporation, and the Land and Water Research and Development Corporation: Canberra.

Oates, N. and Clarke, B. (1987). Trees for the Back Paddock. Goddard and Dobson: Melbourne.

Race, D. (ed.) (1993). Agroforestry: Trees for Productive Farming. Agmedia: East Melbourne.

Saunders, D.A., and Hobbs, R.J. (1995). Habitat reconstruction: the revegetation imperative. Pp 104-112 *in* Conserving Biodiversity: Threats and Solutions. (Eds. R.A. Bradstock, T.D. Auld, D.A. Keith, R.T. Kingsford, D. Lunney and D.P. Siverston). Surrey Beatty and Sons: Chipping Norton, New South Wales.

Venning, J. (1988). Growing Trees for Farms, Parks and Roadsides: A Revegetation Manual for Australia. Lothian Publishing: Melbourne.

Further reading:

Burke (1990), Barker *et al.* (1995), Bird and Cumming (1996), Breckwoldt (1983), Brunet (1996), Campbell *et al.* (1990), Cogger (1994), Costermans (1992), Cremer (1990b), Fuhrer (1993), Garrett (1989), Hirst and Morton (1993), Nadolny (1991), Reid and Wilson (1986), Riemer (1986), Simpfendorfer (1989), Simpson and Day (1996), Stelling (1994), Strahan (1995), Taylor (1994), Triggs (1996), van der Moezel and Bell (1990), van der Moezel *et al.* (1991), Zborowski and Storey (1995).

Summary

Planning revegetation projects requires careful consideration of issues such as the location of planting, selection of plant species, design of planting areas, timing of planting and the most suitable methods for establishing plants. Techniques and approaches for establishing plants in the ground appear to be the most thoroughly studied aspect of revegetation, and there is now a large and growing body of knowledge on species selection and optimum planting procedures for many areas in Australia.

9. Revegetation for nature conservation – lessons from past experience and looking to the future

This literature review has identified four main areas in which there are important lessons we can learn from past experience when considering future directions for revegetation and nature conservation in Australia.

The role of nature conservation in revegetation activities

Past experience shows that in rural environments revegetation activities have been primarily motivated by considerations relating to productive use of the land (e.g. shelter for stock, prevention of erosion, prevention of soil salination). Nature conservation has, at most, been a secondary or incidental objective in many cases (Section 3). Of course, there are also outstanding examples in which the primary objective of revegetation has been nature conservation, but these are uncommon rather than regular occurrences. However, the critical issue is not necessarily the motivation for revegetation but the way in which it is carried out and the extent to which conservation goals have been integrated with other land management goals.

Challenges for the future include:

- more effectively integrating nature conservation goals into the design and planning of revegetation where it is primarily undertaken for reasons other than conservation. This is the subject of a companion report (see Bennett *et al*. 1999);
- assigning greater priority to conservation goals for revegetation where financial assistance is provided by the community, ostensibly to enhance the natural environment (e.g. Natural Heritage Trust); and
- further promoting ways in which individuals and community groups can carry out revegetation to achieve conservation goals.

Lack of knowledge of nature conservation benefits from revegetation

The almost complete lack of published information on the use of revegetated areas by wildlife is a critical and astonishing gap in our knowledge. This must be rapidly addressed if revegetation is to be used effectively for nature conservation and as a tool for landscape-scale restoration and conservation. There are at least four areas in which information is urgently required:

- the range of vertebrate and invertebrate animals that are able to establish populations within revegetated habitats of different plant species composition and vegetation quality, and the extent to which 'intact' communities can be restored in these habitats. For example, to what extent do different groups of animals (e.g. mammals, birds, reptiles, amphibians, invertebrates) utilise revegetated habitats dominated by trees only, compared to those with diverse plant species composition? How do different groups of animals respond to revegetation dominated by indigenous versus non-indigenous species of plants?
- the effects of size and configuration of revegetated patches on the species and communities that occur within them. A particular issue is the ability of different species groups to colonise newly revegetated habitats in relation to the distance of isolation from a 'source' area.
- the extent to which native plant species can re-colonise and establish in revegetated habitats and the types of management intervention needed to facilitate this goal.
- the extent and rate at which ecological processes are restored in revegetated habitats. These include processes such as litter decomposition, nutrient cycling, development of mycorrhizal associations, plant pollination, and predatory and competitive interactions that regulate herbivory.

Integrating management, monitoring and research

Greatest gains in understanding the value of revegetation for nature conservation will be achieved by integrating well-designed monitoring programs with revegetation activities. This type of approach has been used for studying the effects of revegetation on wind speed and stock shelter on farms, and for measuring the effects of revegetation on saline water tables, but has not been used to date in relation to conservation of flora and fauna. Several approaches can be adopted.

Quantitative monitoring of the fauna of selected revegetated areas
Quantitative monitoring in existing revegetated areas of different age, species composition or size would greatly enhance understanding of the use of revegetation (or lack of use) by different faunal groups. Long-term monitoring of selected sites in relation to the age and structure of the vegetation would provide valuable data on habitat relationships and the dynamics of faunal populations in revegetation. Generally it will be more valuable to monitor a small number of revegetation projects (but of an adequate statistical sample size) in a careful quantitative manner than to attempt to monitor many sites in a brief or cursory manner.

Designing revegetation activities in an experimental fashion
Progress in understanding the most effective ways to carry out revegetation for wildlife conservation will be most rapid when the values of different forms of revegetation are experimentally assessed. This could be achieved, for example, by establishing replicate plots that differ in relation to one of the following attributes, and then monitoring the use of each plot by faunal groups:

- size – large versus small plots of revegetation;
- isolation – plots close to, or distant from, 'source' areas;
- shape – linear plots versus compact blocks of the same total area;
- location – plots along gullies or creek lines compared to those on slopes or hill tops; and
- vegetation – plots planted with trees only compared to those with diverse plant species composition.

Such an experimental approach could be integrated into revegetation activities being undertaken by landholders or community groups (e.g. Landcare groups), but monitoring of most faunal groups would need to be undertaken as a scientific project.

Incorporating revegetation into landscape-scale strategies for conservation

Strategies for effective conservation of wildlife must be planned at landscape and regional scales, rather than at a local scale. The need for diverse kinds of vegetation and habitats, the area required for self-sustaining populations of larger or specialized species, and the movement patterns of many animals dictate the need for conservation planning to encompass large areas. Issues relating to the pattern and arrangement of habitats, such as the total area of habitat, representation of different habitat types and connectivity of habitats also need to be considered at this scale. Revegetation will become an increasingly important component of conservation strategies in heavily developed regions because of the need to restore degraded environments. There are several implications.

Planning at a landscape level
Although the task of revegetation is carried out at a local level, planning is needed at a landscape or catchment level so that plantings are complementary and contribute to a broader conservation strategy. If many individuals carry out revegetation independently, a large total area may be planted but its effectiveness for conservation will be diminished compared with the same area planted in a strategic manner.

Re-creating natural vegetation
Where the goal of revegetation is to compensate for past excessive clearing and restore depleted vegetation types, the species composition of the plantings will be important. Further attention needs to be given to developing techniques for restoring and reconstructing vegetation at large scales, both to determine how it can practically be done and what goals in vegetation composition are achievable.

Responsibility for revegetation
Broad-scale restoration and revegetation is unlikely to be achieved by depending solely on private landholders to do the work. The community, through government or other agencies, has a key responsibility in two particular areas:

- the revegetation of larger tracts of vegetation (such as blocks of 20 to 1000 ha in size), which are an essential part of a regional conservation network; and
- revegetation in which the goal is to restore 'natural' vegetation communities.

10. Annotated Bibliography

Abel, N., J. Baxter, J., Campbell, A., Cleugh, H., Fargher, J., Lambeck, R., Prinsley, R., Prosser, M., Reid, R., Revell, G., Schmidt, C., Stirzaker, R. and Thorburn, P. (1997). Design Principles for Farm Forestry: A Guide to Assist Farmers to Decide Where to Place Trees and Farm Plantations on Farms. Rural Industries Research and Development Corporation: Canberra.

Sets out design principles for the use of trees for wood production, shade and shelter, dryland salinity and waterlogging, fodder, soil conservation, nature conservation, and amenity. Each section outlines the value of trees for these purposes, important design features for the particular purpose, and how to monitor the effects of tree establishment.

Abensperg-Traun, M., Smith, G.T., Arnold, G.W. and Steven, D. (1996). The effects of habitat fragmentation and livestock grazing on animal communities in remnants of gimlet *Eucalyptus salubris* woodland in the Western Australian wheatbelt. I. Arthropods. *Journal of Applied Ecology* **33**: 1281-1301.

Effects of habitat fragmentation and livestock activity on arthropod communities were investigated in 26 remnants of gimlet woodland in WA wheatbelt. Small and poorly connected remnants showed highest intensities of disturbance. Examined the relative importance of biogeographic variables and habitat disturbance variables on the occurrence of numerous groups of invertebrates. Habitat disturbance was the major influence on arthropod communities with biogeographic variables explaining limited variation in either abundance or diversity. Discusses implications for management of remnants.

Alexandra, J. (1995). Bush bashing. *Habitat Australia* **23**: Supplement.

Anderson, G.W. (1990). Agroforestry. Pp 405-416 *in* Trees for Rural Australia. (Ed. K.W. Cremer). Inkata Press: Melbourne.

Describes some of the important principles and aspects to consider in planning and managing agroforestry projects. Outlines the system most widespread in Australia at the time of publication.

Andrews, J. (1993). The reality and management of wildlife corridors. *British Wildlife* **5**(1): 1-7.

Discusses the relative importance of corridors for movement of plants, invertebrates, reptiles, amphibians, birds and mammals. Principles for establishing corridors are identified as: (1) provide habitat for species; (2) be as continuous as possible; (3) be of sufficient width; (4) act as stepping stones where cannot be continuous; and (5) link reservoirs of species. Guidelines for design and management are given, including spacing and the need for layers of vegetation. Stresses that enhancement of existing habitat and links is more important than establishing new ones.

Arnold, G.W. (1983). The influence of ditch and hedgerow structure, length of hedgerows, and area of woodland and garden on bird numbers on farmland. *Journal of Applied Ecology* **20**: 731-750.

Censused the number of birds in 37 five ha sites on farmland in Cambridgeshire, England during 1980-81. Ten types of habitat were represented, ranging from arable land to tall hedgerows and linear strips of woodland. Investigated the effects of structural characteristics of hedges and ditches on the number and species of birds utilising them and adjacent arable or grassland. The number of bird species was influenced by the structural complexity of the habitat and surrounding land use. Management practices to enhance bird species utilisation of hedgerow habitats are discussed.

Arnold, G. W. and Weeldenburg, J.R. (1990). Factors determining the number and species of birds in road verges in the wheatbelt of Western Australia. *Biological Conservation* **53**: 295-315.

Censused the avifauna in 1 km sections of roadside vegetation over one year. Assemblages of birds differed between three main vegetation types. Abundance of 20 of 21 commonest species was significantly related to road verge characteristics. Species richness increased with roadside width. Roadside vegetation represents about 10% of native vegetation in the district. Its role in the conservation of the avifauna of the district is discussed.

Arnold, G. W., Steven, D.E., Weeldenburg, J.R. and Smith, E.A. (1993). Influences of remnant size, spacing pattern and connectivity on population boundaries and demography in Euros *Macropus robustus* living in a fragmented landscape. *Biological Conservation* **64**: 219-230.

> A population of euros living in a fragmented landscape was studied by using radio-telemetry to determine movements and population demography to assess long term survival prospects. Animals appeared to be separated into a number of metapopulations, some of which had very small numbers. Within metapopulations, movements of animals between populations were documented, and appeared to depend on stepping stones and habitat corridors. Demographic differences were described between populations with low and high densities.

Asher, S.C. and Thomas, V.G. (1985). Analysis of temporal variation in the diversity of a small mammal community. *Canadian Journal of Zoology* **63**: 1106-1109.

> Surveyed the species and spatial diversity of small mammals occupying fencerow habitats on a farm near Cambridge, Ontario, and used the information to assess the validity of using single-sample surveys to measure small mammal diversity. Nine small mammal species were recorded in fencerows from mid-May to mid-October 1981.

Australian Greenhouse Office (1998). Factsheet: The Greenhouse Effect. Available URL: http://www.greenhouse.gov.au/pubs/factsheets/fs_effect.html (Accessed 21 April 1999).

Australian Greenhouse Office (1999). Australian Greenhouse Office Home Page. Available URL: http://www.greenhouse.gov.au.

Baer, N.W. (1989). Shelterbelts and windbreaks in the Great Plains. *Journal of Forestry* **April**: 32-36.

> Reviews the history of development and benefits of windbreaks and shelterbelts in the Great Plains, South Dakota, USA. Suggests that while windbreaks can be used to control erosion, increase crop yields, protect livestock, control snow, reduce energy utilisation to heat or cool homes, and provide wildlife habitat, the land and maintenance required (e.g. control of competing vegetation, insects and disease) can make it difficult to convince landowners to plant trees.

Baltensperger, B.H. (1987). Hedgerow distribution and removal in nonforested regions of the Midwest. *Journal of Soil and Water Conservation* **January-February**: 60-64.

> Investigates and reviews reasons for hedgerow removal in midwestern America.

Barker, J., Grigg, G. and Tyler, M. (1995). A Field Guide to Australian Frogs. Surrey Beatty and Sons: Chipping Norton, New South Wales.

> Provides a guide to approximately 150 species of frog found in Australia. Identification of each species is made possible by a series of colour photos and taxonomic keys. Descriptions and notes on each species assist with identification. The size, habitat, advertisement call, and breeding and larvae of each species are described. Similar species are listed and diagnostic features which distinguish these species are summarised.

Barr, N. and Cary, J. (1992). Greening A Brown Land. Macmillan Education Australia Pty. Ltd.: Melbourne.

> Provides a historical review of Australia's agricultural practices and traces our search for sustainability.

Barrett, G. (1997). Repairing the rural landscape: Birds on Farms. *Wingspan* **December**: 11-15.

> Discusses preliminary results of the Birds Australia 'Birds on Farms' (BOF) survey. While originally launched as a pilot study in north-eastern Victoria, the BOF survey has now become a national project involving about 320 farms. Participants, primarily farmers, were encouraged to identify and count birds once each season for two years at four half ha sites within a single 50 ha area on their farm. Preliminary results in relation to percentage woodland cover, grazing, presence of native grasses, revegetation, and habitat diversity are provided. The implications of these results for future activities are discussed and a guide for creating an ideal woodland patch is provided.

Barrett, G.W., Ford, H.A. and Recher, H.F. (1994). Conservation of woodland birds in a fragmented rural landscape. *Pacific Conservation Biology* **1**: 245-256.

Assesses the conservation status of 137 species of land birds occurring on the Armidale Plateau of the New England Tablelands, north-east New South Wales. Of these species, six are classified as locally extinct, 18 are thought to be declining and uncommon, 35 are common but vulnerable due to their dependence on healthy woodland, and 33 species are abundant on the Tablelands. The remaining 45 species were likely to have never been common in the area. The conservation status of these birds is used to demonstrate that placing emphasis on the conservation of regionally rare species and species highly sensitive to disturbance may lead to unrealistic management advice, which may ultimately be detrimental to the regional fauna. It is also suggested that pastoral areas may be better defined as variegated rather than fragmented landscapes.

Baudry, J. (1989). Hedgerows and hedgerow networks as wildlife habitat in agricultural landscapes. Pp 111-124 *in* Environmental Management in Agriculture: European Perspectives. (Ed. J.R. Park). Belhaven Press: London.

Briefly reviews wildlife in the hedgerow network landscapes of Europe, outlines landscape structure and hedgerow species composition, and comments on the design of hedgerow network landscapes within the agricultural framework.

Bennett, A. F. (1987). Conservation of mammals within a fragmented forest environment: the contributions of insular biogeography and autecology. Pp 41-52 *in* Nature Conservation: The Role of Remnants of Native Vegetation. (Eds. D. A. Saunders, G. W. Arnold, A. A. Burbidge and A. J. M. Hopkins). Surrey Beatty and Sons: Chipping Norton, New South Wales.

Two conceptual approaches were used to evaluate the effects of habitat fragmentation on native mammals in a study area in south-western Victoria. Biogeographic studies of 39 forest patches were used to examine the factors influencing species richness in forest remnants, and the change in faunal composition in relation to remnant size. An ecological study of the population ecology of the Long-nosed Potoroo was carried out to provide an autecological perspective on habitat fragmentation. These approaches provide useful but complementary information on the impacts of fragmentation on native mammals.

Bennett, A.F. (1988). Roadside vegetation: a habitat for mammals at Naringal, south-western Victoria. *Victorian Naturalist* **105**: 106-113.

Describes the results of a survey of mammals in roadside vegetation at 15 sites at Naringal, south-western Victoria. At least 18 of 23 species of mammals (excluding bats) known from the area used roadside vegetation in some way. Roadside vegetation provides some species with additional foraging habitat, for others a refuge from disturbance, and for others it is a habitat in which they may live. Emphasizes the value of roadside vegetation for conservation, especially when the composition and structure of the vegetation are similar to that of natural forest habitats.

Bennett, A. F. (1990a). Land use, forest fragmentation and the mammalian fauna at Naringal, south-western Victoria. *Australian Wildlife Research* **17**: 325-347.

Documents land use, clearing of forest and the process of habitat fragmentation for a 200 km^2 study area in south-western Victoria. Describes the result of a survey of 39 forest patches and uses this data, together with historical information, to describe the conservation status of the mammalian fauna of this area. Four general recommendations for conservation of the mammal fauna include: the importance of a regional perspective in planning, the need to maintain a substantial total area of forest, the importance of maintaining and enhancing continuity between forest remnants, and the protection of habitat components essential to native mammals.

Bennett, A.F. (1990b). Habitat Corridors: Their Role in Wildlife Management and Conservation. Department of Conservation and Environment: Melbourne.

Reviews the role of habitat corridors in wildlife management and conservation with particular reference to the wildlife and environments of southern Australia, particularly south-eastern Australia.

Bennett, A.F. (1991). Roads, roadsides and wildlife conservation: a review. Pp 99-118 *in* Nature Conservation 2: The Role of Corridors. (Eds. D.A. Saunders and R.J. Hobbs). Surrey Beatty and Sons: Chipping Norton, New South Wales.

> Presents a comprehensive review of literature from Australia and the world on the relationship between road systems and wildlife. Five functions of roads systems were considered: the role of roads and roadside vegetation as a habitat for animals; the effect of road systems as a barrier to the movement of animals; the extent and impact of road kills on wildlife populations; the use of roads and roadside vegetation as a conduit for animal movements; and the role of road systems as a source of ecological effects on the surrounding environment.

Bennett, A.F. (1999). Linkages in the Landscape: The Role of Corridors and Connectivity in Wildlife Conservation. IUCN: Gland, Switzerland.

> A thorough examination of the role of connectivity and ecological linkages in wildlife conservation, with case studies and examples from throughout the world. The book has three sections: (1) defining the issues; (2) the values of linkages for wildlife conservation; and (3) incorporating linkages into conservation strategies and appropriately designing and managing them for conservation. Case studies and examples are provided throughout.

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**: 244-261.

> Examines the effects of land use and habitat change on land birds of the Northern Plains region of Victoria. Data from the Atlas of Australian Birds were used in a model to determine factors influencing species presence or absence for 63 landscapes (15 x 18.5 km grid cells). Different components of the avifauna responded in different ways to landscape patterns and change. Richness of woodland birds was best predicted by total tree cover and number of streams. 'Other' birds were more evenly distributed across the region and species richness was best predicted by rainfall and temperature gradients. Landscapes of high conservation value for birds are those with (1) extensive tree cover; (2) large blocks of habitat; (3) streamside vegetation; and (4) habitats linked by networks of streams or roadsides.

Bennett, A. and Platt, S. (1996). Wildlife on the farm. Pp 23-36 *in* From the Ground Up – Property Management Planning Manual. (Ed. P. Dixon). Department of Conservation and Natural Resources and Department of Agriculture: Melbourne.

> Outlines three basic principles for integrating wildlife habitats with sound farm management and production in Victoria:
>
> 1) conserving native vegetation and wildlife offers a range of benefits to farm enterprises;
> 2) conserving wildlife on farms can make a valuable contribution to overall conservation goals; and
> 3) wildlife and wildlife habitats can be practically integrated with sound farm management.
>
> Provides advice on gathering information on native vegetation and wildlife on an individual property and/or the surrounding area and includes sources of information for Victoria. Discusses how to develop and map property plans, and manage farm habitats for wildlife

Bennett, A.F., Henein, K. and Merriam, G. (1994). Corridor use and the elements of corridor quality: chipmunks and fencerows in a farmland mosaic. *Biological Conservation* **68**: 155-165.

> Studied the use of fencerow corridors by the Eastern Chipmunk *Tamias striatus* in four woods and 18 fencerows in farmland near Ottawa, Canada. Chipmunks were present in all woods and in many fencerows, with extensive movement apparent within and between landscape elements. Chipmunks used corridors in two main ways – as residents or transients. Residents lived within and along many fencerows, favouring those with tall trees and a woodland structure. Transient chipmunks were trapped only once in a fencerow and were presumed to use the fencerow network as a path through farmland. Linear continuity was the most important attribute influencing the presence of transient chipmunks. Implications for corridor use and metapopulation function, and corridor management and restoration are discussed.

Bennett, A., Brown, G., Lumsden, L., Hespe, D., Krasna, S. and Silins, J. (1998). Fragments for the Future: Wildlife in the Victorian Riverina (the Northern Plains). Department of Natural Resources and Environment: Melbourne.

> Describes the past and present wildlife of the Victorian Riverina. Provides guidelines for managing the regions' wildlife and preventing further declines.

Bennett, A.F., Kimber, S.L. and Ryan, P.A. (1999). Revegetation and Wildlife: Enhancing Revegetated Habitats for Wildlife Conservation in Rural Environments. Report to Environment Australia: Canberra.

Complementary report to this literature review. Presents a series of principles for ways in which the value of revegetation as a habitat can be increased. Principles are based on an hierarchy in land management, including the site level, the block level, the landscape and the region.

Bentley, J.M. and Catterall, C.P. (1997). The use of bushland, corridors and linear remnants by birds in southeastern Queensland, Australia. *Conservation Biology* **11**: 1173-1189.

Addresses the value of corridors as habitat for birds but does not directly consider movement. Riparian areas within continuous bushland supported a higher species richness and abundance of birds than dryland areas, possibly due to higher moisture and nutrient levels, increased structural complexity and increased plant productivity. Higher abundances of 'cleared land' or 'edge' species were found in linear strips and more 'forest' or 'bushland-dependent' species in continuous bushland. Effects of isolation were only evident for resident bushland-dependent species.

Best, L.B. (1983). Bird use of fencerows: implications of contemporary fencerow management practices. *Wildlife Society Bulletin* **11**: 343-347.

Presents results of a census of birds along three types of fencerows in Story County, Iowa, USA. Fencerows with greater coverage of trees and shrubs were found to support a more diverse and abundant avifauna (48 species) than fencerows with scattered trees and shrubs (38 species) or herbaceous fencerows (12 species). The importance of these results in relation to current (1983) fencerow removal and management is discussed.

Best. L.B., Freemark, K.E., Dinsmore, J.J. and Camp, M. (1995). A review and synthesis of habitat use by breeding birds in agricultural landscapes of Iowa. *American Midland Naturalist* **134**: 1-29.

Compiles information on the composition, abundance and nesting status of bird species during the breeding season for habitats characteristic of the agricultural landscapes of Iowa, USA. Data for 114 bird species in 20 habitats was obtained from 60 sources. Of the 114 bird species recorded, 73 were recorded in shelterbelts and fencerows. While the total number of breeding bird species was higher in forests than in small grains and herbaceous fencerows, bird species were more abundant in strip-cover habitats such as fencerows, shelterbelts, and railroad right-of-ways than other habitats.

Biddiscombe, E.F. (1985). Bird populations and farm plantations in the Hotham River Valley, W.A. *Western Australian Naturalist* **16**: 32-39.

Investigated bird species within three farm plantations in Western Australia. Species diversity within the plantations reflected those of nearby remnants. Despite seasonal fluctuations, bird populations increased with increasing plantation height and crown cover. With increasing age, more food resources became available. Eucalypts began flowering after about three years providing a source of nectar for honeyeaters and buds for parrots. The availability of nesting sites changed over time. In the early stages of development, some species utilised ungrazed pasture or the dense low tree canopy. After two years, Yellow-rumped Thornbills nested in the dense crowns of *Casuarina* sp. Other species were first recorded nesting after three years and Red Wattlebird after four years. Concludes that plantations will be exploited by local populations of birds. Food and nesting resources change over time and plantations need to be within territorial reach, present frequent flowering, and have a mixed structure, particularly for the benefit of small birds.

Bird, R. and Cumming, K. (1996). Establishment and management of trees for shelter, conservation and agroforestry. Pp 37-62 *in* From the Ground Up – Property Management Planning Manual. (Ed. P. Dixon). Department of Conservation and Natural Resources and Department of Agriculture: Melbourne.

Discusses the establishment and management of trees for shelter, conservation and agroforestry in a series of sections. These are: planning for tree planting; establishment of trees and shrubs from seedlings; establishment of trees and shrubs by direct seeding; natural regeneration of trees and shrubs; shelterbelts for farms; agroforestry options; and pruning and coppicing of woodlots.

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

Provides a review of the 'current' (1992) knowledge of the role of trees for improving productivity and sustainability of agricultural practices in Australia. The extent and causes of land degradation, primarily soil and water erosion, are detailed for Australia. Wind erosion is the primary issue addressed as an incentive for planting shelterbelts. Examples of the extent of shelterbelt establishment in other countries is provided and used to emphasise the lack of knowledge and effort made in Australia given the extent of the problems identified for states most affected by wind erosion – New South Wales, Victoria, Tasmania and Western Australia. Concludes that shelterbelts can assist in mediating the impacts of erosion and improving productivity. Details of the design for effective shelter are provided including spacing and types of trees. Agroforestry systems are encouraged as a further economic incentive to plant shelterbelts. Suggestions are made for further research into the biological and economic effects of shelterbelts.

Bowden, J. and Dean, G.J.W. (1977). The distribution of flying insects in and near a tall hedgerow. *Journal of Applied Ecology* **14**: 343-354.

Measured the patterns of distribution of insects in and near a tall (7m) complex hedgerow at Rothamsted. More insects were trapped on the western side of the hedgerow irrespective of wind speed and direction. This pattern of distribution was attributed to the comparative richness of the vegetation, with the western side having the greater floristic diversity.

Bradley, J. (1991). Bringing Back the Bush: The Bradley Method of Bush Regeneration. Ure Smith Press: Willoughby New South Wales.

Outlines principles and techniques for bush regeneration developed by Eileen and Joan Bradley.

Brandenburg, S.A. and Majer, J.D. (1995). A database for revegetated areas in the Tammin region of Western Australia: implications for land owners, managers and researchers. Pp 258-270 *in* Nature Conservation 4: The Role of Networks. (Eds. D.A. Saunders, J.L. Craig and E.M. Mattiske). Surrey Beatty and Sons: Chipping Norton, New South Wales.

Presents a case study outlining the process involved in surveying revegetated areas and the value of the 'South Tammin Catchment Database for Revegetated Areas' to land owners, managers and researchers. This chapter describes the development and exploration of the database and the attributes of revegetated areas within the catchment, but focuses particularly on the importance of linkages between the fore mentioned parties in developing the database.

Breckwoldt, R. (1983). Wildlife in the Home Paddock: Nature Conservation for Australian Farmers. Angus and Robertson Publishers: Melbourne.

Discusses the need to conserve wildlife on Australian farms and addresses issues such as planning for wildlife, wildlife corridors, tree decline, revegetation techniques (regeneration and planting), management of wildlife habitat, and wildlife pests and their control and management. The aim is to assist farmers, extension officers, resource managers and planners to include wildlife on the land.

Breckwoldt, R. and Gorrie, I. (1990). Living Corridors: Conservation and Management of Roadside Vegetation. Greening Australia Limited: Canberra.

Discusses the benefits of roadsides and provides practical advice amount managing and conserving remnants in Australia. Includes case studies provided by a range of additional authors.

Brenner, F.J. and Kelly, J. (1981). Characteristics of bird communities on surface mine lands in Pennsylvania. *Environmental Management* **5**: 441-449.

Observed a total of 55 bird species on reclaimed surface mine lands in Pennsylvania, USA. Forty-one of these species (74.5%) were summer residents, the remainder either visitors or permanent residents. Bird communities and individual species were correlated with plant species composition and vegetation structure on the mines with bird species composition changing in response to successional vegetation stages from grassland to forest communities. Concludes that surface mined lands have the potential to support abundant bird populations and other wildlife, and reclamation efforts should be devised to create a diversity of both terrestrial and aquatic habitats.

Brenner, F.J., Kelly, R.B. and Kelly, J. (1982). Mammalian community characteristics on surface mine lands in Pennsylvania. *Environmental Management* **6**: 241-249.

Studied mammalian communities on 10 surface mines in Mercer County, Pennsylvania, USA, over a four year period. The size, composition and spatial distribution of mammalian communities were related to the amount, height, density (structure) and composition of the plant community. Native plant species were of greater importance in determining size and composition of mammalian communities than those used in reclamation. Concludes that surface mines will support a variety of mammalian species, the composition of which largely depends on the amount and type of vegetation found in the area.

Brodie, L., Roxburgh, J. and Whiley, L. (1991). Bush Regenerators' Handbook. National Trust of Australia (NSW).

Provides practical advice on planning and implementing a bush regeneration project. Includes techniques for weed removal and advice on where to go for further information.

Bromham, L., Cardillo, M., Bennett, A.F., and Elgar, M.A. (1999). Effects of grazing by stock on the ground invertebrate fauna of remnant woodland. *Australian Journal of Ecology*.24: 199-207.

Surveys of ground-dwelling invertebrates were carried out in ungrazed woodland remnants, grazed remnants and cleared pasture to examine the effect of grazing on invertebrates. Ungrazed remnants had a higher diversity of invertebrate orders than the other types of sites, particularly due to greater representation of the rare invertebrate orders. Abundance of invertebrates was greatest in pasture sites and was dominated by taxa associated with grassy and open habitats.

Brown, G. and Bennett, A. (1995). Reptiles in Rural Environments: The Distribution, Habitat Requirements and Conservation Status of the Reptile Fauna of the Murray-Darling Basin Area in Victoria. A report to the Murray Darling Basin Commission. Department of Conservation and Natural Resources: Melbourne.

Describes the results of a survey of reptiles in different types of remnant vegetation in the Northern Plains region, Victoria. One ha sites in roadside vegetation, along streams, in four size-classes of remnant vegetation, and among scattered trees in pasture were sampled. The abundance of reptiles was very low, and many sites had no species recorded. The reptile fauna at most sites was dominated by a few common and widespread species. The richest sites for reptiles were generally those where ground vegetation remained and provided a complex habitat structure at the ground layer. Implications for the conservation of reptiles in remnant vegetation are discussed.

Brunet, B. (1996). Spiderwatch: a Guide to Australian Spiders. Reed Books: Melbourne.

A comprehensive guide to Australian spiders. More than 100 of the most frequently encountered spiders are depicted and most are described in detail including information on toxicity, distribution, habitat and prey capture. Spiderwatch is an easy-to-use and practical field manual illustrated with a key guide, colour drawings and photographs to assist with identification. Advice on first aid is also included.

Buchanan, R.A. (1996). Bush Regeneration: Recovering Australian Landscapes. TAFE: Sydney.

Developed as a student learning publication, 'Bush Regeneration' introduces the value of bushland and techniques to restore and manage bushland in Australia. Includes sections on plant identification and ecology, weed identification, regeneration techniques, and regeneration of plant communities, and discusses severely degraded landscapes, bushland management and project organisation.

Burel, F. (1989). Landscape structure effects on carabid beetle spatial patterns in western France. *Landscape Ecology* **2**(4): 215-226.

Investigated the spatial distribution of carabid beetles in a hedgerow network landscape in western France. Forty-two carabid taxa were recorded in a network study (12 forest species) and 54 species in a study of lanes. The spatial distribution of species was related to their biological characteristics (forest core, forest peninsula or forest corridor species). The abundance and number of species decreased with increasing distance from forest. A dense herbaceous layer and presence of a tree layer (enhanced in double hedgerows) play major roles in the survival of forest carabid species outside forest. Analysis of carabid spatial distribution in the hedgerow network was used to discuss the role of the landscape among other levels of ecological organisation.

Burel, F. (1992). Effect of landscape structure and dynamics on species diversity in hedgerow networks. *Landscape Ecology* **6**(3): 161-174.

Presents results of a survey of the spatial distribution of carabid beetles in hedgerows in Lalleu, France. This paper analyses how the structure and dynamics of a hedgerow network landscape over the 30 years prior to 1992 had affected carabid beetles in hedgerows.

Burel, F. (1996). Hedgerows and their role in agricultural landscapes. *Critical Reviews in Plant Sciences* **15**(2): 169-190.

Reviews the ecology of hedgerows and their ecological role agricultural landscapes. Includes historical information on the development of rural landscapes in western Europe and discussion of hedgerows as wildlife corridors.

Burel, F. and Baudry, J. (1990). Hedgerow network patterns and processes in France. Pp 99-120 *in* Changing Landscapes: An Ecological Perspective. (Eds. I. S. Zonneveld and R. T. T. Forman). Springer-Verlag: NewYork.

Reviews research into the ecology of hedgerows and hedgerow networks, although most research has focused on individual hedgerows. Relates the results to principles of landscape ecology.

Burel, F. and Baudry, J. (1995). Social, aesthetic and ecological aspects of hedgerows in rural landscapes as a framework for greenways. *Landscape and Urban Planning* **33**: 327-340.

Concerns about the clearing of hedgerows in western Europe prompted a study in Brittany, France. This involved interviewing farmers and non-farmers, and conducting a landscape survey to bring together human perceptions of the value of hedgerow networks with landscape ecological values. There were contrasting opinions between farmers and non-farmers, but agreement on the need to retain hedgerows as part of the cultural landscape. Most were unaware of the ecological role of hedgerow networks. Suggested that a better understanding of hedgerows as a means to sustain agricultural productivity and to protect natural resources would facilitate their integration in farm and landscape design. The influence of hedgerow management on landscape stability is discussed and a general eco-visual planning guide for the design of a new hedgerow network is proposed. Principles for sustaining ecological functioning include designing a network which permits control of waterflow to prevent erosion and ensure field drainage, maintaining hedgerows between major soil units, and maintaining networks to allow wildlife movement through the landscape.

Burke, S. (1990). Growing Trees by Direct Seeding. Department of Conservation and Environment: Melbourne.

Small handbook providing practical information relating to the establishment of trees by sowing seed directly onto an area (direct seeding) including site preparation, seed collection and seeding techniques.

Burke, S. and Wilson, A. (eds) (1995). A Haven from Storm and Drought: The Role of Trees in Sustainable Agriculture – Workbook 3. Greening Australia Ltd., Rural Industries Research and Development Corporation, and the Land and Water Research and Development Corporation: Canberra.

Final in a three-part series on 'The Role of Trees in Sustainable Agriculture' developed from papers presented to a National Conference in 1991, the first to bring together research highlighting the importance of trees on farms. This final workbook describes how shelterbelts can benefit almost every property in Australia to some extent by providing either shelter or fodder, or in some cases, both. It looks at how a shelterbelt works, describes the benefits a shelterbelt can provide and includes a guide of how to plan and establish shelterbelts. Also explores the role of forage trees and shrubs as an addition to pastures on broadacre farms. Provides case studies to illustrate the information provided.
Two other workbooks in this series are:

- Putting Back the Bush: The Role of Trees in Sustainable Agriculture – Workbook 1. Guest editor Nan Oates
- Making Farm Trees Pay: The Role of Trees in Sustainable Agriculture – Workbook 2. Guest editor Rowan Reid

Burke, S., Campbell, A. and Robertson, D. (1988). Shelterbelts. Department of Conservation, Forests and Lands and Potter Farmland Plan: Melbourne.

Booklet which discusses reasons for establishing shelterbelts (e.g. farm productivity, fire protection, wildlife habitat, control of erosion and salinity), layout and design, and maintenance and management of shelterbelts.

Busche, G. (1997). Population dynamics of breeding birds of farmland with hedges and human settlements in western Schleswig-Holsteid, 1960 to 1995. [German]. *Vogelwelt* **118**(1): 11-32.

Population sizes of birds breeding in farmland with hedges and human settlements were studied in the county of Dithmarschen, Germany. Between 1987 and 1995, 66 species were recorded in farmland with hedges while 73 species were recorded in human settlements (15-19 species only after 1960). Population trends are given for species which occurred with more than 10 pairs/year since 1960. Found loss of farmland with hedges to development led to reductions in the breeding pairs of some species whilst providing breeding opportunities for other species. Conservation measures and management are discussed.

Cable, T.T. (1991). Windbreaks, wildlife and hunters. Pp 35-55 *in* Wildlife and Habitats in Managed Landscapes. (Eds. J.E. Rodiek and E.G. Bolen). Island Press: Washington DC.

Provides a brief history of windbreak planting and reviews literature pertaining to both wildlife populations in windbreaks and the design of windbreaks for wildlife. Concludes with a socio-economic study of the use of windbreaks by hunters.

Cable, T. T. and Cook, P.S. (1990). The use of windbreaks by hunters in Kansas. *Journal of Soil and Water Conservation* **45**: 575-577.

Presents results of a questionnaire sent to 1,501 randomly selected licensed hunters in Kansas to determine the amount of hunting done in windbreaks, types of game species sought, and which windbreak features affected the quality of their hunting. Kansas hunters spend an average of 40.7% of their time in, or adjacent to, windbreaks (the equivalent of 1.37 million hunter-days annually), most commonly to pursue quail, pheasant and deer. The most important windbreak attributes were adjacent plants/crops, ground cover and vegetation density while proximity to a farmstead and height of trees were the least important characteristics. Implications for windbreak design and future use by hunters are discussed.

Cale, P. (1990). The value of road reserves to the avifauna of the central wheatbelt of Western Australia. *Proceedings of the Ecological Society of Australia* **16**: 359-367.

Assesses the value of road reserve vegetation to bird communities of the Kellerberrin District, WA. Over a 12 month period, a total of 60 species or 88% of the district's terrestrial avifauna were recorded in road reserves. The species complement in road reserves was determined by vegetation type. Species richness in woodland vegetation was related to vegetation structure and density. Species richness in mallee/shrubland road reserves was influenced by width of vegetation. Some temporal variation was found in species composition and density due to changing resource availability. This emphasises the need to study a system over an extended period and to consider individual species requirements when evaluating a system for management purposes. Generally, maximising width and increasing structural diversity of the vegetation should increase species richness.

Cameron, R.A., Down, D.K. *et al*. (1980). Historical and environmental influences on hedgerow snail faunas. *Biological Journal of the Linnean Society* **13**(1): 75-88.

Studied the composition and diversity of hedgerow snail faunas in three areas of the English Midlands, UK. Snail faunas are influenced by historical and environmental differences between hedges, with soil acidity and climate being the most important. Hedges originating in or near woodland have richer faunas than those planted in open fields. Snail diversity increased with age of hedges although only slightly in hedges over 100 years old. These differences are considered to be primarily due to poor dispersal of snails rather than environmental differences between hedges of differing age and origin.

Campbell, A. (1991). Planning for Sustainable Farming: The Potter Farmland Plan Story. Lothian Publishing: Melbourne.

Explains for land users how to better understand and manage their land. The book works through a whole farm planning process and offers detailed practical advice on how to prepare a farm plan, improve farm layout, treat land degradation, and revegetate (including sections on establishing and protecting farm trees and shelterbelt design). Cases studies from the Potter Farmland Plan are used to illustrate the planning process for blending conservation with productivity.

Campbell, A. (1994). Landcare: Communities Shaping the Land and the Future. Allen and Unwin Ptd. Ltd.: St Leonards, New South Wales.

Tells the story of Landcare and how local communities, rural communities in particular, can work together to tackle their own problems.

Campbell, R., Chandler, R. and Thomas, G. (1990). Victoria Felix: Improving Rural Land with Trees. Department of Conservation and Environment and Graduate School of Environmental Science, Monash University: Melbourne.

Aims to promote community concern for planting, regenerating and maintaining trees on Victorian farms. Use of indigenous trees is advocated. Includes sections addressing: the relationships between trees and farming; financial benefits of trees in the rural landscape including animal production, the effects of shelterbelts on plant growth, soil conservation, ecological benefits, amenity, property values and the greenhouse effect; trees and farm layout; revegetation techniques including nursery practice, natural regeneration, direct seeding and planting; managing remnant vegetation; wildlife conservation; fire and farm protection; and reasons for tree decline.

Capel, S. W. (1988). Design of windbreaks for wildlife in the Great Plains of North America. *Agriculture, Ecosystems and Environment* **22/23**: 337-347.

Discusses optimal windbreak designs to benefit the wildlife of the Great Plains, North America.

Caughley, J. and Gall, B. (1985). Relevance of zoogeographical transition to conservation of fauna: amphibians and reptiles in the south-western slopes of New South Wales. *Australian Zoologist* **21**: 513-529.

Describes the results of a survey of reptiles and amphibians in a number of conservation reserves and forest blocks in southern NSW. Major factors influencing the composition and richness of the fauna were the position of the reserve in relation to zoogeographical regions, and the reserve size.

Chapman, M. (1990). Amenity. Pp 336-356 *in* Trees for Rural Australia. (Ed. K.W. Cremer). Inkata Press: Melbourne.

Outlines general principles for creating a visually pleasing and environmentally sensitive landscape. Provides suggestions for landscaping to achieve a pleasant environment with shelter from wind, sun and bushfires on both individual properties and around rural towns.

Charles Sturt University and Orange Agricultural College, University of Sydney (1997). Save the Bush Toolkit. Charles Sturt University Printery: Bathurst, New South Wales.

This toolkit has been developed as a guide for people planning to 'save the bush' in the central western district of New South Wales, however, the principles can be applied to regions across Australia with additional advice from professionals in the local area.

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. Pp 378-386 *in* Conservation Outside Nature Reserves. (Eds. P. Hale and D. Lamb). The University of Queensland: Brisbane.

Investigated the influence of trees on biodiversity in grazed open-forest with a sparse shrub layer and grazed long-cleared natural pastures with recently established windbreaks. Although significantly fewer in number than in mature forest, more microarthropod species were found beneath windbreaks than in open pasture (although these were primarily introduced or cosmopolitan species which had formed distinct communities). Concludes that retention or restoration of tree cover will help conserve diversity of soil biota and indigenous herbs in grazed landscapes of the Northern Tablelands, New South Wales.

Clugston, B. (1992). Battling the odds–wildlife habitat on an irrigation property. *Land for Wildlife News* **1**(6): 6.

Short article outlining a 'Wildlife on Farms' demonstration project which started in the mid-to-late 1970's to illustrate the benefits of revegetation for wildlife. Alan and Mary Burgess invited several Government agencies to create wildlife habitat on their 35 ha dairy farm in irrigation country north of Shepparton, Victoria. In 1979, the bird count was just 24 species and by 1992 this count had risen to 110 species.

Cogger, H.G. (1994). Reptiles and Amphibians of Australia. 5th Edition. Reed Books: Sydney.

A comprehensive, fully illustrated guide to Australia's herpetofauna. Over 960 species of reptiles and amphibians are described with distribution maps and photos. Keys to each of the families are provided and a guide to collecting, storing or preserving specimens is included. Also includes first aid techniques.

Collins, B.G., Wykes, B.J. and Nichols, O. (1986). Recolonisation of restored bauxite minelands by birds in southwestern Australian forests. Pp 341-354 *in* Birds of Eucalypt Forests and Woodlands: Ecology, Conservation, Management. (Eds. A. Keast, H.F. Recher, H. Ford and D. Saunders). Surrey Beatty and Sons: Chipping Norton, New South Wales.

Discusses research relating to bird communities within unmined Jarrah forest and their recolonisation of rehabilitated bauxite mining sites. The avifauna of unmined and restored habitat is compared and likely long-term trends are discussed. An outline of bauxite mining and rehabilitation procedures is provided and suggestions are made for further research.

Commonwealth of Australia (1998a). The National Greenhouse Strategy – Strategic Framework for Advancing Australia's Greenhouse Response. Australian Greenhouse Office: Canberra.

Commonwealth of Australia (1998b). Greenhouse Challenge Vegetation Sinks Workbook – Quantifying Carbon Sequestration in Vegetation Management Projects. Australian Greenhouse Office: Canberra.

Conyers, T. (1986). Hedgerow and ditch removal in south east Essex, England, 1838-1984. *Biological Conservation* **38**: 233-242.

Outlines the process of hedgerow and ditch removal in an agricultural area in south-east Essex, England, between 1938 and 1984 using maps, aerial photographs and field survey results as source materials. Discusses the implications of hedgerow removal for conservation of wildlife on farms.

Cook, P.S. and Cable, T.T. (1995). The scenic beauty of shelterbelts on the Great Plains. *Landscape and Urban Planning* **32**: 63-69.

Addresses the declining quantity and quality of shelterbelts on the Great Plains despite their recognised agricultural and non-agricultural benefits. Shelterbelts contribute to the scenic beauty of the plains landscape, however, perceptions of beauty may be influenced by the overall landscape image. Plant species, arrangement and shape of shelterbelts may also contribute to perception of beauty and seasonal differences may also exist. Familiarity with the landscape may also alter perceptions. An economic value for beauty would encourage protection and enhancement of shelterbelts.

Costermans, L. (1992). Native Trees and Shrubs of South Eastern Australia. Rigby Publishers.

Provides a comprehensive guide to the native trees and shrubs of south-eastern Australia. Places of special interest, and landforms and associated vegetation are described. Regional guide-lists are provided along with descriptions and illustrations of the leaves, flowers, distribution and growth form of each species.

Crane, W.J.B. (1990). Planting of trees. Pp 145-153 *in* Trees for Rural Australia. (Ed. K.W. Cremer). Inkata Press: Melbourne.

Outlines general guidelines for planting trees and ensuring their establishment (survival through their first season).

Cremer, K.W. (ed.) (1990a). Trees for Rural Australia. Inkata Press: Melbourne.

Aims to motivate landholders by addressing the benefits of trees on farms. The book provides advice on how to achieve these benefits and also outlines underlying principles to promote understanding and to enable advice to be evaluated and adapted to each situation. Covers a range of topics in independently authored chapters, including: potential productivity of a site; site selection; species selection and nursery practice; methods of putting trees back on the land (natural regeneration, direct seeding and planting); aftercare for trees including equipment required; farm planning issues; benefits of trees; economics involved; and sources of advice or assistance.

Cremer, K.W. (1990b). Choosing the right species. Pp 17-75 *in* Trees for Rural Australia. (Ed. K.W. Cremer). Inkata Press: Melbourne.

Aims to assist with the correct choice of species to be planted for various purposes throughout Australia by providing an introduction to the relative merits of native and introduced species and the characteristics required for different purposes. The need to match species not only to climate but local site and soil conditions is also considered. A table lists over 200 species with sufficient details to make a preliminary selection, followed by more detailed description of the distribution, ecological requirements and growth form of each species.

Crome, F., Isaacs, J. and Moore, L. (1994). The utility to birds and mammals of remnant riparian vegetation and associated windbreaks in the tropical Queensland uplands. *Pacific Conservation Biology* **1**: 328-343.

This study aimed to determine which species of birds and mammals utilised remnant riparian vegetation and four windbreaks planted in 1972 and 1977 on a farm on the Atherton Tablelands. The windbreaks were useful for birds, but were little used as habitat for mammals. The complex remnant vegetation of the creek system was utilised more readily by both birds and mammals and the most complex of windbreaks was most utilised by birds. Suggestions for future tree planting schemes aiming to augment wildlife habitat include: do not replace native remnants; provide complex structure with a shrub layer; and if possible, retain shrubby remnants, even those with lantana.

CSIRO Australia (1999). CSIRO Australia Home Page. Available URL: http//:www.csiro.au/index.html

Dambach, C. (1945). Some biologic and economic aspects of field border management. *Transactions of the North American Wildlife Conference* **10**: 169-184.

Davidson, R. and Davidson, S. (1992). Bushland on Farms – Do You Have a Choice? Australian Government Publishing Service: Canberra.

Centred on the Northern Tablelands of NSW, the primary objective of the book is to argue against the use of pesticides by highlighting means of reducing insects naturally by restoring natures' balance. The benefits of wildlife for insect pest control is emphasised and the role of trees in encouraging wildlife is discussed. Ecological interactions including parasitism and predation are outlined and wildlife requirements for food and shelter are illustrated. The current problems being faced in agricultural landscapes (more specifically the Northern Tablelands) are illustrated using an explanation from the perspective of early settlers and the challenges they faced in taming the unfamiliar land. The need for change in land management is emphasised and suggestions of how to facilitate this change through farm plantings are outlined. The value of trees for pest control, productivity and general aesthetics is illustrated using case studies.

Deacon, J.N. and Mac Nally, R. (1998). Local extinction and nestedness of small-mammal faunas in fragmented forest of central Victoria, Australia. *Pacific Conservation Biology* **4**: 122-131.

A survey of small mammals was undertaken in 8 forest fragments and 5 reference areas within dry forests of central Victoria. All sites were impoverished. Small ground mammals were scarce in both fragments and continuous forest, but arboreal marsupials were much more abundant in fragments. There was a significant 'nesting' of mammals in fragments as a function of fragment size – small fragments supported a subset of the fauna in larger fragments. Habitat modification, especially loss of large trees, appears to have an important influence on the fauna in large continuous forests, and greater availability of large trees in fragments accounts for their greater abundance of arboreal mammals.

Department of Arts, Heritage and Environment (1985). Think Trees, Grow Trees. Australian Government Publishing Service: Canberra.

A compilation of lectures from an education course given in Canberra as part of the National Tree Program. This book aims to stimulate interest in the value of trees for the land and wildlife. It provides practical guidelines for growing trees for woodlots, shelterbelts and agroforestry, including a section on how to raise your own seedlings. An example is given of a property which has been growing trees for agroforestry for 30 years. Advice is given as to the role of governments and community groups in assisting with putting trees back on the land.

Department of Environment, Sport and Territories (1995). Native Vegetation Clearance, Habitat Loss and Biodiversity Decline: An Overview of Recent Native Vegetation Clearance in Australia and its Implications for Biodiversity. Biodiversity Series, Paper No. 6. Department of Environment, Sport and Territories: Canberra.

Presents an overview of native vegetation clearance in Australia and its contribution to biodiversity decline. Summarises recent native vegetation clearance in Australia and by State and Territory.

Department of Environment, Sport and Territories (1996). The National Strategy for the Conservation of Australia's Biological Diversity. Department of Environment, Sport and Territories: Canberra.

Presents the National Strategy for the Conservation of Australia's Biological Diversity which aims to protect biological diversity and maintain ecological processes and systems. The strategy meets the requirements of the National Strategy for Ecologically Sustainable Development and complements the National Forest Policy Statement, National Greenhouse Response Strategy and draft strategy entitled Conservation of Australian Species and Ecological Communities Threatened with Extinction – A National Strategy.

Dixon, P. (ed.) (1996). From the Ground Up – Property Management Planning Manual. Department of Conservation and Natural Resources and Department of Agriculture: Melbourne.

Provides a compilation of background information and advice on various issues relating to property management planning. Sections by various authors include: construction of a property management plan; soils and their management; wildlife on the farm; establishment and management of trees for shelter, conservation and agroforestry; seed collection techniques; wetlands; soil erosion and its management; salinity management; fire prevention planning; pest animal management; weed management; farm water supply; pasture management; environmental considerations and pastures on dairy farms; electric fencing; and implementation and budgeting for a property management plan.

Doran, J.C. (1990). Seed collection. Pp 77-88 *in* Trees for Rural Australia. (Ed. K.W. Cremer). Inkata Press: Melbourne.

Discusses methods of collecting, extracting and storing seed. Includes summary table of seed viabilities, pre-treatment and seed storage requirements for species.

Doran, J.C. and Turnbull, J.W. (eds.) (1997). Australian Trees and Shrubs: Species for Land Rehabilitation and Farm Planting in the Tropics. Australian Centre for International Agricultural Research: Canberra.

Includes independently authored sections on the Australian environment, Australian vegetation, selection of species and provenances for planting, and seed nursery practice and establishment. Species digests provide detailed descriptions of 112 major species and 52 minor species with potential to provide fuelwood, fodder, posts, poles, shade and shelter, ground cover, or other desirable products or influences.

Dorricott, K. and Roberts, B. (1993). Wildlife Conservation on Planned Properties: A Guidebook for Queensland Landholders. Land Use Study Centre, University of Queensland: Toowoomba.

A guidebook compiled specifically to assist Landcare groups and others involved in property planning in Queensland to integrate wildlife conservation in land management planning. Includes the following chapters: conservation in rural Queensland – a framework for action; landuse planning; planning flora and fauna protection; wildlife conservation in practice - guidelines for managing species and habitat; harvesting wildlife; and studying nature.

Downes, S. J., Handasyde, K.A., Elgar, M.A. (1997). The use of corridors by native mammals in fragmented eucalypt forest in north-eastern Victoria, Australia. *Conservation Biology* **11**: 718-726.

Studied the use of forested roadside corridors by mammals in north-eastern Victoria by sampling at replicate sites in forest blocks, in roadsides both 'near' (300 m) and 'far' (1500 m) from forest, and in open pasture. Few mammals were detected in pasture but roadsides were used by many species. The number of species using corridors far from forest was fewer than at sites near to forest. Different species used the roadsides in different ways. Concludes that while corridors provide useful habitat for many species they may not provide a complete solution to the problem of fragmentation.

Dramstad, W.E., Olson, J.D. and Forman, R.T.T. 1996. Landscape Ecology Principles in Landscape Architecture and Land-use Planning. Island Press: Washington DC.

Explores the principles of landscape ecology. Fifty-five concepts or principles are presented in four groups - patches (size, shape and location), edge/boundaries, connectivity (corridors or stepping stones), and mosaics (networks, fragmentation and scale). Provides examples of practical application of landscape principles including 14 case studies from around the world.

Dunger, W. (1989). The return of soil fauna to coal mined areas in the German Democratic Republic. Pp 307-337 *in* Animals in Primary Succession: The Role of Fauna in Reclaimed Lands. (Ed. J.D. Majer). Cambridge University Press: Cambridge.

Describes recolonisation patterns of soil invertebrates on 40 rehabilitated coal mine dumps over a 25 year period in Germany. The most important factor influencing soil fauna recolonisation was identified as moisture (e.g. the hydrologic regime and the influence of vegetation on evapotranspiration), while the amount of dead organic matter produced by developing vegetation was considered of secondary importance. Small mammals had a direct influence on soil structure with their network of subterranean galleries perforating the soil. Between 7 and 14 years after rehabilitation, the species composition of the small mammal community resembled unmined woodlands. Practical implications of soil zoological studies in rehabilitation are discussed. Argues that pedozoology is an important component of rehabilitation research.

Eckersley, R. (1989). Regreening Australia: The Environmental, Economic and Social Benefits of Reforestation. Occasional Paper No. 3. CSIRO Australia.

Presents a national program to 'regreen Australia' involving growing billions of trees and other plants over 10-20 years. This program would provide a range of environmental, economic and social benefits to Australia. In addressing the issues, the report identifies the need to combat land degradation, counter the greenhouse effect, increase agricultural productivity, boost timber production, enhance the beauty of the Australian bush (i.e. nature conservation and aesthetics), generate jobs, create an export industry, and in so doing, encourage a national unity and a new optimism.

Eldridge, J. (1971). Some observations on the dispersion of small mammals in hedgerows. *Journal of Zoology* **165**: 530-534.

Hedges at two sites in England were surveyed to determine which species of small mammals inhabit hedgerows. Seven species were captured, although only three species of rodent are discussed. The use of habitat varied between these species with proportions of each influenced by ground layer density. Short-tailed Voles *Microtus agrestis* were found predominantly in the part of hedge bordering rough grassy fields while Bank Voles *Clethrionomys glareolus* remained in the hedge and comprised a much larger proportion of the total rodent fauna in hedges with denser undergrowth. Wood Mice *Apodemus sylvaticus* were the only species that ventured into the surrounding field.

Emmerich, J.M. and Vohs, P.A. (1982). Comparative use of four woodland habitats by birds. *Journal of Wildlife Management* **46(1)**: 43-49.

Compares bird species diversity, species richness, population density and habitat use of individual bird species in riparian woodlands, tree claims, multi-row shelterbelts and single-row windbreaks in the Great Plains, South Dakota, USA. Regardless of breeding, spring migration or winter seasons, bird species richness and diversity were highest in the riparian woodlands and tree claims (mean plot size 2.9 ha and 3.6 ha respectively) while density was highest in shelterbelts and windbreaks (mean plot size 1 ha and 0.5 ha respectively). Concluded that diversity of birds in woodlands of the Great Plains depends primarily on maintenance of riparian woodland habitat and presence of tree claims. Programs to enhance shelterbelts should not overshadow the importance of retaining the larger, structurally diverse riparian woodlands and tree claims.

Environment Australia (1999). *Endangered Species Protection Act 1992* Schedules 1, 2 and 3 – 22 July 1999. Available URL: http://www.biodiversity.environment.gov.au/plants/threaten/lists/esp_lists/sched1.html (Accessed 3 December 1999).

Fleury, A.M. and Brown, R.D. 1997. A framework for the design of wildlife conservation corridors: with specific application to southwestern Ontario. *Landscape and Urban Planning* **37**: 163-186.

Used information from the literature to develop a 'framework for the design of wildlife corridors'. Five types of corridors were identified: remnant, planted, regenerated, disturbed, and environmental resource. Functions include: conduit, barrier or filter, habitat, and an influence on the surrounding matrix (a source of environmental and biotic effects). Critical attributes affecting corridor quality were identified as: matrix (surrounding land use), patch (size and shape), network connectivity, barriers, length, width, shape, edge, structure, and composition. Suggestions for corridor design were made on the basis of guilds of animals rather than single-species. Diagrams of habitat requirements of guilds are provided together with a framework for design of wildlife corridors. Tables identifying habitat requirements of guilds are included as well as a case study applying the principles to a complete watershed or catchment.

Ford (undated). Farm Birds: Nature's Pest Controllers. Pamphlet. Department of Arts, Heritage and Environment: Canberra.

Discusses the role of farm birds in controlling invertebrate pests. Includes suggestions for establishing vegetation to encourage birds including design and composition (including plant species and other habitat components).

Ford, H.F. and Bell, H. (1981). Density of birds in eucalypt woodland affected to varying degrees by dieback. *Emu* **81**: 202-8.

Presents data on the occurrence and densities of bird species in several study sites in the New England Tablelands, NSW, including those heavily affected and little affected by dieback of eucalypt trees. The implications of differences in the composition and density of the avifauna between sites are discussed.

Forman, R.T.T. (1995). Land Mosaics: The Ecology of Landscape and Regions. Cambridge University Press: Cambridge.

A standard international text that comprehensively outlines and reviews the field of landscape ecology. Includes sections on landscapes and regions, patches, corridors, mosaics and flows, and changing mosaics. Extensively referenced to source material from many countries.

Forman, R.T.T. and Baudry, J. (1984). Hedgerows and hedgerow networks in landscape ecology. *Environmental Management* **8**: 495-510.

Discusses the role of hedgerows and hedgerow networks as ecological systems within agricultural landscapes using information from Europe, England and USA. The many biological, economic and sociological functions of hedgerows and networks are identified and the influence of structure, dynamics and management are discussed. Direct and indirect evidence for use of hedgerows by plants and animals is examined. Concludes that hedgerows provide food and cover for many species, and function as corridors for movement across the landscape. Species diversity within hedgerows is influenced by vegetation structure and composition, which in turn varies with origin (planted, spontaneous and remnant), farming practices in adjacent fields and hedgerow management practices. Most species in hedgerows are characteristic of forest edges although species composition varies with proximity and abundance of woods (remnants).

Fortin, D. and Arnold, G. W. (1997). The influence of road verges on the use of nearby small shrubland remnants by birds in the central wheatbelt of Western Australia. *Wildlife Research* **24**: 679-689.

Studied variation in bird abundance in 13 small remnants in farmland in the WA wheatbelt, isolated by distances of 70-600 m from remnant roadside vegetation. The structural attributes of roadsides and the avifaunal composition on roadsides were frequently more important predictors of numbers of the most common 19 species than were structural attributes in the remnants. Diversity of bird species decreased with distance from the roadside vegetation. The value of small remnants of vegetation as part of the conservation network decreases with their isolation, and is strongly linked to the use of road verges.

Fowler, D.K. (1989). The return of vertebrate fauna to surface coal mined areas in Tennessee. Pp 371-396 *in* Animals in Primary Succession: The Role of Fauna in Reclaimed Lands. (Ed. J.D. Majer). Cambridge University Press: Cambridge.

Investigated the return of breeding birds and small mammals to mine interior, edge and woodland habitats on two surface coal mined sites in Tennessee, USA. Thirty-five species of breeding birds were recorded in June 1980 in woodland (22 species) and rehabilitated mined land (17 species). Ten species of small mammal were recorded in woodland and rehabilitated mined land. Discusses the implications of findings for featuring wildlife in mine rehabilitation practices.

Fox, B.J. and Fox, M.D. (1984). Small-mammal recolonisation of open-forest following sand mining. *Australian Journal of Ecology* **9**: 241-252.

Reports changes in populations of introduced House Mouse *Mus musculus* and native New Holland Mouse *Pseudomys novaehollandiae* during the first 10 years of regeneration of coastal open-forest at Myall Lakes National Park after clearing for mineral sand mining between 1971 and 1983. House Mouse was the first small-mammal colonist present whose population density increased rapidly to a maximum at three years following regeneration, after which it declined. New Holland Mouse first appeared between 4-5 years and peaked between 8-9 years, after which it also declined. Concludes that the species replacement observed suggests competitive interaction between these species and the study confirms the seral positions of rodent species in succession following disturbance such as mining or fire.

Francis, J. (1997). Revegetation brings back the birds: survey backs benefits. *Australian Farm Journal* **June**: 66-67.

Briefly outlines the 'Birds on Farms' survey and discusses some preliminary results. These include the species of birds increasing and decreasing on farms, the threat of noisy miners, importance of native grasslands, differences between the number of bird species found on farms with little tree cover versus those with extensive cover, and the effect of different farming enterprises on bird species.

Fritz, R. and Merriam, G. (1993). Fencerow habitats for plants moving between farmland and forests. *Biological Conservation* **64**: 141-148.

In response to a lack of evidence that fencerows or hedgerows serve as corridors for plant movement, the study was established to compare spontaneously regenerated fencerows with forest edges in the Great Lakes-St Lawrence Forest Region of Canada. Three species of forest-floor herb were transplanted to test whether environmental conditions within fencerows allow the growth and survival of dispersing herbs. Habitat quality must support the growth of arriving plant species. Habitat suitability is influenced by vegetation structure and composition, and orientation of fencerows which influences exposure to environmental elements (e.g. wind and sunlight). Concluded that although some herbs occur in fencerows, habitat conditions in fencerows were unsuitable for the growth of the three transplanted species. There is no clear evidence that forest plants use fencerow corridors for movement except when carried by an animal.

Fuhrer, B. (1993). A Field Companion to Australian Fungi. 2nd Edition. Field Naturalists Club of Victoria: Melbourne.

A guide to 138 species of Australian fungi. Includes information to assist in the identification of fungi, and descriptions of their natural habitat and edibility. Each description is accompanied by a colour photograph.

Fuller, R.J., Trevelyan, R.J. and Hudson, R.W. (1997). Landscape composition models for breeding bird populations in lowland English farmland over a 20 year period. *Ecography* **20**: 295-307.

Assessed the components of landscape structure in lowland English farmland which could best predict patterns in bird community composition, total bird density and densities of 12 bird species. Data were derived from mapping censuses at four-yearly intervals between 1966 to 1986 and yearly samples of bird community composition. The implications of the results for landscape design and management, and the relative contribution of woodland and hedgerows to bird communities in farmland landscapes is discussed.

Garrett, B.K. (1989). Whole Farm Planning: Principles and Options. Department of Conservation, Forests and Lands: Melbourne.

A booklet with information for farmers to help identify the management and development options to be considered when developing a whole farm plan.

Gilbert, O.L. and Anderson, P. (1998). Habitat Creation and Repair. Oxford University Press: New York.

Provides a practical guide to habitat creation primarily for Europe and the United Kingdom. Discusses the ethics and principles of habitat creation and provides details for designing and creating grassland, woodland, scrub and hedgerow, heath and moor, montane and submontane, coastal, farmland and wetland habitats.

Goldney, D.C. and Bowie, I.J.S. (1990). Some management implications for the conservation of vegetation remnants and associated fauna in the central western region of New South Wales. *Proceedings of the Ecological Society of Australia* **16**: 427-440.

Describes the magnitude and intensity of European occupation of the Central Western Region of New South Wales, one of the oldest and most disturbed human-dominated regions in Australia. Discusses the loss of species and habitat in this area and describes measures to conserve and protect the remaining areas of natural vegetation and associated fauna.

Goulburn Broken Catchment and Land Protection Board (1997). Regional Catchment Strategy. Goulburn Broken Catchment Management Authority: Shepparton.

Green, R.E., Osborne, P.E. and Sears, E.J. (1994). The distribution of passerine birds in hedgerows during the breeding season in relation to characteristics of the hedgerow and adjacent farmland. *Journal of Applied Ecology* **31**: 677-692.

Surveyed passerine birds in hedgerows on 46 farms in lowland England during the breeding season. Of the 18 bird species recorded, most preferred tall hedges with many trees, although there were differences among bird species. General features found to influence bird species were the structure of habitat, the number and type of plant species, and surrounding land use. The effect of various management practices on the incidence of bird species was also investigated and discussed.

Greening Australia Victoria (1997). Direct Seeding and Mechanical Planting Guide – Western District of Victoria. Greening Australia Victoria: Melbourne.

Guide compiled by Greening Australia Victoria (GAV) to provide basic key information on direct seeding and mechanical planting techniques for landholders in south western Victoria participating in the Alcoa Revegetation Assistance Program.

Greenslade, P. and Majer, J.D. (1993). Recolonisation by Collembola of rehabilitated bauxite mines in Western Australia. *Australian Journal of Ecology* **18**: 385-394.

Collembola are among the earliest colonisers of newly created habitat and, as decomposers, are a functionally significant group in the soil system. Species richness of Collembola was positively correlated with plot age, plant species richness and diversity and also with percentage plant cover and quantity of organic residues, namely litter. Presence of logs and other soil factors may play a role in determining the return of collembolan species to rehabilitated sites.

Greenwood, E.A.N. (1986). Water use by trees and shrubs for lowering saline groundwater. *Reclamation and Revegetation Research* **5**: 423-434.

Develops a rationale for using vegetation to lower water tables on which the likelihood for success of a revegetation program may be assessed. The rate of transpiration, groundwater recharge and aquifer yield per unit change in water table elevation can be used to predict the ability of vegetation to lower a water table. Some options for vegetation strategies are developed and examples described. A guide to semi-quantitative methods of assessing water uptake by vegetation is included.

Gretton, P. and Salma, U. (1996). Land Degradation and the Australian Agricultural Industry. Industry Commission: Canberra.

Explores the relationships between agricultural production, profitability and land degradation, and some of the broad issues affecting land management. Undertaken as part of a statutory obligation of the Industry Commission to report on the performance of the Australian Agricultural Industry.

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

Describes an experimental study to test the hypothesis that Noisy Miners affect the diversity and abundance of bird communities by aggressive exclusion of small birds. Bird censuses were carried out in three small remnant woodlands where Noisy Miners were excluded and also in three control sites where no removal occurred. Following removal there was a major influx of honeyeaters and other insectivorous birds. At two of the removal sites there was a significant increase in bird diversity and abundance, and at the third an increase in diversity (but not abundance), compared with control sites. Noisy Miners did not reinvade during the following 16 months. Long-term monitoring is required to determine the implications for tree health.

Gruttke, H. and Kornacker, P.M. (1995). The development of epigeic fauna in new hedges – a comparison of spatial and temporal trends. *Landscape and Urban Planning* **31**: 217-231.

Studied the colonisation of a linear sequence of nine young hedge plantations (each 400 m^2) by epigeic (surface-dwelling) arthropods in an intensively cultivated landscape about 30 km west of Bonn, Germany. The investigation began in 1982 when the new hedges were planted, and concluded in 1991. During this time, 57 carabid species (Carabidae), 95 spiders (Araneida) and nine harvestmen (Opilionida) were recorded in the plantation strip compared to a respective 85, 121 and 11 species captured in the study area as a whole (includes old semi-natural habitat of wooded and meadowed habitats). The results showed: (1) comprehensive spatial and long-term temporal data are complementary and a combination of both is recommended; (2) development towards a typical hedge fauna progresses very slowly despite high temporal dynamics in species abundance and differences between the three taxa considered; and (3) small, nine year old hedges do not function well as stepping stones for the dispersal of epigeic arthropods, and only a small corridor effect could be established.

Haas, C.A. (1995). Dispersal and use of corridors by birds in wooded patches on an agricultural landscape. *Conservation Biology* **9**: 845-854.

Movement patterns of three migratory bird species were investigated in woody draws (native woodlands along drainage lines) and shelterbelts in Sioux Country, south-central North Dakota, USA. Most movements occurred over relatively short distances within a shelterbelt. However, movement of adults between shelterbelt sites occurred significantly more frequently between sites connected by a wooded corridor than between unconnected sites.

Haas, C. (1997). What characteristics of shelterbelts are important to breeding success and return rate of birds? *American Midland Naturalist* **137**(2): 225-238.

Studied breeding bird populations in 52 shelterbelts (16 sites) and 4 woody draw sites in Sioux County, south central North Dakota, USA. A total of 42 species were documented nesting in wooded habitat on the study area. The composition of breeding bird species in shelterbelts (artificial habitats) was similar, but not identical, to native (woody draw) habitats with 23 of 42 species nesting in both habitats. Characteristics of shelterbelts that influence nesting success and return rate of three migratory passerines – American Robin *Turdus migratorius*, Brown Thrasher *Toxostoma rufum* and Loggerhead Shrike *Lanius ludovicianus* – are examined including landscape-level and macrohabitat characteristics such as isolation, area and grazing status of a site.

Hadden, S. A. and Westbrooke, M.E. (1996). Habitat relationships of the herpetofauna of remnant buloke woodlands of the Wimmera Plains, Victoria. *Wildlife Research* **23**: 363-372.

Reptiles and amphibians were surveyed in 12 woodland remnants dominated by Buloke in western Victoria. Nine reptile and four amphibian species were recorded. Species richness of total herpetofauna and of reptiles was related to vegetation understorey structure and past grazing pressure. Area of remnant was not a significant correlate of herpetofaunal richness. Species richness of amphibians was best predicted by soil type. Implications for management of Buloke woodlands are discussed.

Haines, P. and Burke, S. (1993). Benefits of shelterbelts for farm production. Pp 37-44 in Agroforestry: Trees for Productive Farming. (Ed. D. Race). Agmedia: East Melbourne.

Discusses the design and layout of shelterbelts and benefits of shelter for grazing and crop production. Expected benefits of shelterbelts at maturity are presented in a table. Research into crop yields at Rutherglen, Victoria is outlined. Rod Bird provides a section on benefits for grazing enterprises from an economic perspective (profitability).

Hale, P. and Lamb, D. (1997). Conservation Outside Nature Reserves. Centre for Conservation Biology, The University of Queensland: Brisbane.

This book is the product of a conference 'Conservation Outside Nature Reserves' held in 1996 to explore means of protecting biological diversity at a landscape scale while achieving primary production in the rangelands, agricultural landscapes and forests of Australia. Contributions examine on-ground aspects of maintaining viable ecosystems, economic incentives to landholders, and legislative and planning initiatives. The contributors also include people working the land to achieve viable production and nature conservation. From a hands-on perspective, they describe the processes, the costs, the problems and how to overcome them in an Australian context.

Harms, W.B. and Knaapen, J.P. (1988). Landscape planning and ecological infrastructure: the Randstad study. Pp 163-167 *in* Connectivity in Landscape Ecology. (Ed. K-F Schreiber). Munster Geographische Arbeiten: Munster.

Examines the concept of ecological infrastructure, a concept which evolved from landscape planning. Addresses whether there is a need for such a new concept and, if it is justified, whether this concept is applicable for landscape planning. Uses reafforestation in the western part of the Netherlands (the Randstad) as a case study to examine the applicability of the concept of ecological infrastructure. The Randstad is the area encompassing the four largest cities of the Netherlands: Amsterdam, The Hague, Rotterdam and Utrecht.

Harrison, B. (1993). Tree planting for erosion control. Pp 213-216 *in* Agroforestry: Trees for Productive Farming. (Ed. D. Race). Agmedia: Melbourne.

Describes how trees can help control soil erosion and outlines how to chose the correct trees to perform this function for a given site.

Henderson, M.T., Merriam, G. and Wegner, J. (1985). Patchy environments and species survival: chipmunks in an agricultural mosaic. *Biological Conservation* **31**: 95-105.

> Investigates the movements of chipmunks among several woodland isolates in a farmland mosaic in Canada. Fencerows were found to serve as movement corridors and also as habitat for small breeding populations. Experimental local extinctions of chipmunks received non-reproductive young immigrants within one or two months and redeveloped successful breeding populations by the second summer.

Hill, C. J. (1995). Linear strips of rainforest vegetation as potential dispersal corridors for rainforest insects. *Conservation Biology* **9**: 1559-1566.

> To assess the potential for streamside strips of rainforest vegetation to act as habitat corridors for invertebrates, surveys were carried out in intact rainforest, rainforest edges, linear strips and in arable land. Analysis was restricted to the four most abundant species in the rainforest interior for each of the groups, ants, dung beetles and butterflies. All four species of ants, three species of butterflies and one dung beetle species were present in streamside strips, suggesting that these strips have the potential to maintain connectivity for rainforest invertebrates through an inhospitable farmland environment.

Hingtgen, T.M. and Clark, W.R. (1984). Small mammal recolonisation of reclaimed coal surface-mined land in Wyoming. *Journal of Wildlife Management* **48**: 1255-1261.

> Compares small mammal populations on reclaimed coal surface-mined land reseeded two and 3-5 years previously with unmined rangeland. Recorded eight species of small mammals on the 3-5 year old reclaimed area compared with six on two year old areas and five on unmined rangeland. Deer Mice *Peromyscus maniculatus* dominated the community on all reclaimed areas and Masked Shrews *Sorex cinereus* and Northern Grasshopper Mice *Onychomys leucogaster* where captured almost exclusively on 3-5 year old reclaimed land and unmined rangeland. After two years, total small mammal density was found to remain relatively constant, and diversity of the community increased.

Hino, T. (1985). Relationships between bird community and habitat structure in shelterbelts of Hokkaido, Japan. *Oecologia* **65**: 442-448.

> Examines the relationship between bird community and habitat structure in shelterbelts of the Ishikari district, Japan. The shelterbelts of Hokkaido have been categorised into two types: natural broad-leaved deciduous woods, and various-aged plantations that were established about 60 years ago. They are 30-90 m wide and 550-600 m long; and differ from narrow shelterbelts such as tree rows, described in other studies. Bird species which frequent the forest edge accounted for more than 70% of bird populations in shelterbelts. Forest age variables were correlated with density and species richness in outside-foraging guilds, presumably because of increased availability of nest sites. In all other guilds, vegetation cover was correlated with bird density, and species richness positively correlated with tree species complexity. Positive effects of vegetation cover were attributed to availability of nesting sites, foraging sites and protection from predators. Concludes that bird species diversity is closely related to tree species complexity and bird species richness increases with tree species diversity.

Hirst, F. and Morton, P. (1993). Property management planning: preparing and using a farm plan. Pp 13-22 *in* Agroforestry: Trees for Productive Farming. (Ed. D. Race). Agmedia: Melbourne.

> Outlines how to prepare and use a property management plan.

Hobbs, R.J. (1992). The role of corridors in conservation: solution or bandwagon? *Trends in Ecology and Evolution* **7**: 389-392.

> Addresses whether the value of corridors for facilitating faunal movement and reducing extinction probabilities is ‘now’ better supported by available data, and whether the ‘current’ emphasis on corridors for conservation is justified.

Hobbs, R.J. (1993a). Can revegetation assist in the conservation of biodiversity in agricultural areas? *Pacific Conservation Biology* **1**: 29-38.

Discusses the need for revegetation, the lack of knowledge of benefits for nature conservation, and the limited number of existing guidelines to assist with designing revegetation programs for biodiversity. A key question is posed: *"Can conservation biologists suggest design principles for revegetation which allow optimal placement of revegetation with respect to landscape characteristics, distribution of remnants and faunal requirements?"* Three main ways in which revegetation could enhance conservation of biodiversity are identified. Revegetation can provide buffer strips to protect existing remnants, corridors to increase connectivity between remnants, or additional habitat. Cost-benefit analysis will also play a role in determining the extent and location of revegetation activities. Current levels of degradation in agricultural landscapes need to be reduced to support a nature conservation system and the role of revegetation in achieving this is discussed. Comparison is made between minesite rehabilitation and revegetation of agricultural lands, and fundamental differences between these practices are identified and discussed.

Hobbs, R.J. (1993b). Effects of landscape fragmentation on ecosystem processes in the Western Australian wheatbelt. *Biological Conservation* **64**: 193-201.

Argues that the effects of fragmentation on ecosystem processes – e.g. the hydrologic cycle, nutrient cycling, radiation balance and wind regime – are just as important to the long term conservation of biota in remnant areas. Reviews the clearing and fragmentation of native vegetation in the Western Australian wheatbelt and the subsequent changes in ecosystem processes. Concludes that management of remnant vegetation needs to be carried out in the context of the overall landscape.

Hobbs, R.J. (1997). The right path or roads to nowhere? *Nature Australia* **Autumn** 56-63.

Outlines research examining the issue of corridors in Australia. While studies of animals have suggested that at least some species use corridors for movement or habitat, critics have argued that there is a lack of conclusive evidence and that corridors may also have negative effects (e.g. the spread of weeds or disease). While there is not enough data to convince skeptics that corridors are useful, scientists are faced with a conundrum because of the cost and likelihood of acquiring the necessary data. Corridors on their own are an inadequate response to conservation problems in modified landscapes. They need be integrated into a strategy based on conservation networks. Existing nature reserves and remnant vegetation on private land need to be protected and managed because they form the core areas for conservation; a skeleton on which restoration and revegetation can be based.

Hobbs, R. J. and Atkins, L.A. (1988). Effect of disturbance and nutrient addition on native and introduced annuals in plant communities in the Western Australian wheatbelt. *Australian Journal of Ecology* **13**: 171-179.

Studied the factors affecting the ability of introduced species to invade natural communities in Western Australia. The response of native and introduced annuals to soil disturbance and fertilizer addition was examined. Growth of both native and introduced species is limited by nutrient availability in the communities studied, but introduced species respond more to a combination of nutrient addition and soil disturbance.

Hobbs, R.J. and Hopkins, A.J.M. (1990). From frontiers to fragments: European impact on Australia's vegetation. *Proceedings of the Ecological Society of Australia* **16**: 93-114.

Identifies four major land use categories for Australia on the basis of the degree of modification to the natural vegetation: 1) removal (complete removal of native vegetation); 2) replacement (removal of native vegetation and replacement with intensively managed systems); 3) utilisation (exploitation of native vegetation, with some consequent degree of modification); and 4) conservation (maintenance of natural vegetation for conservation and scientific purposes with minimum deliberate modification of natural processes). Discusses how ecosystem components such as soil properties, hydrology, nutrient cycling, population processes and community properties, are likely to be affected by human modification. Presents prescriptions for rehabilitation or reconstruction of ecosystems based on mitigation of these impacts.

Hobbs, R.J. and Norton, D.A. 1996. Towards a conceptual framework for restoration ecology. *Restoration Ecology* **4**: 93-110.

Identifies the need to develop restoration methods that are applicable at the landscape level. Key components of restoration are outlined: identifying and dealing with degrading processes; determining goals and establishing measures of success; developing methods for implementing goals; incorporating goals into land planning and management strategies; and monitoring restoration and assessing its success.

Hobbs, R.J. and Saunders, D.A. (1991). Re-integrating fragmented landscapes: a preliminary framework for the Western Australian wheatbelt. *Journal of Environmental Management* **33**: 161-167.

Outlines a preliminary framework for an integrated approach to land use planning in the Western Australian wheatbelt to allow simultaneous achievement of multiple goals. Retention of existing remnant vegetation, rehabilitation of degraded areas, and revegetation of key landscape segments are all essential components of this approach. These components need to be co-ordinated to achieve maximum benefit for the goals of sustainable agricultural production, optimal water use and distribution, and maintenance of the diversity of flora and fauna. An integrated approach to landscape management could be adapted to other agricultural areas of the world to benefit both agriculture and nature conservation.

Hobbs, R. J. and Saunders, D.A. (eds) (1993). Reintegrating Fragmented Landscapes: Towards Sustainable Production and Nature Conservation. Springer-Verlag: New York.

Presents a compilation of independently-authored chapters addressing the reintegration of fragmented landscapes using the Western Australian wheatbelt as a case study. Section 1 presents background information such as the history of landscape development. Section 2 addresses landscape disintegration, including changes in biota, soil properties and hydrological balance. Section 3 addresses landscape reintegration including ecological and economic considerations, long-term costs and benefits of alternative farm plans, and conservation management in fragmented systems. The final section presents conclusions on whether reintegration of fragmented landscapes is possible.

Hobbs, R. J., Saunders, D.A. and Arnold, G.W. (1993). Integrated landscape ecology: a Western Australian perspective. *Biological Conservation* **64**: 231-238.

Outlines the tendency for various management authorities (e.g. landholders, nature conservation authority, road management authority) to manage different components of landscapes as separate entities rather than as functionally interdependent elements. Recommends that managers take an integrated approach to the management of the landscape to meet objectives of conservation and production. Such a management approach is developed with particular relevance to the Western Australian wheatbelt, although a similar approach will be relevant in any region where landscape fragmentation has occurred.

Hook, R.A. (1998). Landscape structure and function - the fundamental causes of land and water degradation. Pp 121-131 *in* Farming Action - Catchment Reaction: The Effect of Dryland Farming on the Natural Environment. (Eds. J. Williams, R.A. Hook and H.L. Gascoigne). CSIRO Publishing: Melbourne.

Explores how changes to landscape processes operating in natural systems can cause land degradation. Landscape processes are the material and energy transfers/flows formed by integrated functioning of the biota, soil and land. Three primary processes are identified: conversion of solar energy to plant material; the hydrological cycle; and nutrient cycling and chemical transformations. Aiming to achieve ecologically sustainable agriculture involves practices by which changes to natural processes do not lead to new equilibria associated with degradation. Basic landscape elements are identified as climate, geology, vegetation, regolith and soil, and topography.

Howe, R. W. (1984). Local dynamics of bird assemblages in small forest habitat islands in Australia and North America. *Ecology* **65**: 1585-1601.

Studied the avifauna of small forest isolates in eastern NSW and Wisconsin USA to compare the effects of forest fragmentation on the composition and dynamics of local bird assemblages. In both study areas there were common patterns of distribution among forest isolates despite taxonomic differences. Area was the best predictor of species richness in isolates and in control plots in continuous forest. Species assemblages in isolates differed in composition from those in control plots, and those in isolates were generally more predictable over space and time.

Howe, R. W., Howe, T.D., and Ford, H.A. (1981). Bird distributions on small rainforest remnants in New South Wales. *Australian Wildlife Research* **8**: 637-651.

Birds were censused in 15 small patches (0.08-2.5 ha) of subtropical rainforest in north-eastern NSW. The number of resident species ranged from 1 – 19, and were added in a rather predictable order from small to larger areas. Area was the best single predictor of richness, but isolation, disturbance by stock and distance to water also contributed.

Humphreys, W.F. and Kitchener, D.J. (1982). The effect of habitat utilisation on species-area curves: implications for optimal reserve area. *Journal of Biogeography* **9**: 391-396.

Species recorded during surveys of vertebrates in conservation reserves in the WA wheatbelt were assigned to different habitat utilisation categories based on their dependence on native vegetation. The species-area relationships for these different groups show different patterns, suggesting that there are important implications for conservation.

Hunter, M.J. (1996). Fundamentals of Conservation Biology. Blackwell Science: Cambridge, Massachusetts.

The maintenance of biodiversity through management of ecosystems and populations is the primary focus of this book. The chapters follow a sequence which address the meaning of conservation and biodiversity at a range of biological scales, how biodiversity is threatened and can be maintained. A discussion of the human aspects of conservation biology are interwoven through the text and addressed within a separate chapter. Examples are provided from around the world addressing a range of environments and taxa.

Hussey, B.M.J. and Wallace, K.J. (1993). Managing Your Bushland. Department of Conservation and Land Management: Perth.

A practical guide for people wanting to preserve or expand native bush on their property. Includes sections addressing the value of remnant vegetation, planning, collecting information, principles of native flora and fauna management, problem plants and animals, fire management, regeneration and replanting, and sources of further information. Presented as a guide for Western Australian landowners but is also relevant information for landowners throughout Australia.

Jackson, L., Lopouknine, N. And Hillyard, D. (1995). Ecological restoration: a definition and comments. *Restoration Ecology* **3**: 71-75.

Relates the Society for Ecological Restoration (SER) definition of ecological restoration as "the process of repairing damage caused by humans to the diversity and dynamics of indigenous ecosystems" (p.71). Several points are included to elaborate this definition including: judgement of need, an ecological approach, setting goals and evaluating success, and identifying limitations.

Jentzsch, M. (1992). Avifauna of a field hedgerow in the Goldene Aue area with results of banding breeding birds [German]. *Beitraege zur Vogelkunde* **38**(5-6): 335-347.

Members of a youth club of the Spengler-Museum Sangerhausen Germany examined the presence and birthplace fidelity of birds in a copse of the agricultural landscape Goldene Aue from 1983 to 1990. A total of 62 species was found including 22 nesting species and one nest parasite. Five species breed regularly, nine irregularly and 8 seldomly in the copse. Concludes that copses are important as a permanent breeding habitat for birds.

Johnson, R.J. and Beck, M.M. (1988). Influences of shelterbelts on wildlife management and biology. *Agriculture, ecosystems and environment* **22/23**: 301-335.

Provides an extensive review of the value of shelterbelts for wildlife. Benefits include protection from the elements, escape or refuge cover, reproductive habitat, food and foraging sites, and travel corridors. Wildlife use of shelterbelts in relation to each of these benefits is illustrated using examples from studies primarily in America. The effect of wind on thermoregulation, insulation and heat transfer mechanisms in wildlife is outlined. Design of shelterbelts for wildlife is addressed in terms of size, age, vegetation composition, features of adjacent habitat, and economic considerations. Because shelterbelts are not usually established to benefit wildlife, specific recommendations for research that integrates the desired goals with the needs of wildlife are included. Tables summarise the results of studies into the use of shelterbelts by wildlife. Bird species are listed according to the degree to which they benefit from shelterbelts. Of 108 species reported, 29 are considered to benefit substantially, 37 moderately and 42 very little or use shelterbelts accidentally. Benefits from shelterbelts are summarised in three categories: foraging; nesting or other activities; and resting (activity not associated with reproduction). A similar table is provided for 30 mammal species.

Johnston, P. and Don, A. (1995). Grow Your Own Wildlife: How to Improve Your Local Environment. Greening Australia Ltd: Canberra.

A guide to incorporating wildlife in local environment plans beginning with summary information on reasons to conserve wildlife and basic ecological principles. Most of the book comprises descriptions of projects nominated for the 1988 Tree Care Award under the categories of: wildlife conservation as the prime objective; agricultural land; public reserves, arboreta and institutions; rehabilitation of disturbed lands; house grounds; and tourism and recreation.

Johnston, P.J.M. and Williams, R.D. (1991). Management of native vegetation for timber, land protection and conservation. *In* The Role of Trees in Sustainable Agriculture – A National Conference. Proceedings. (Ed. R. Prinsley). Bureau of Rural Sciences: Canberra.

> Presents an overview of information on managing native vegetation to produce timber and achieve land protection and conservation. Issues emerging are outlined and include the need to promote retention and management of native vegetation. Factors critical for sustainability are identified as the location, size and shape of the vegetated area with key locations including watercourses and in water recharge zones.

Kabay, E.D. and Nichols, O.G. (1980). Use of Rehabilitated Bauxite Mined Areas in the Jarrah Forest by vertebrate Fauna. Environmental Research Bulletin No. 8. Alcoa of Australia Limited: Perth.

> Outlines the results of Alcoa's program to monitor the return of fauna to various rehabilitated bauxite mined areas and discusses the factors influencing faunal return to these areas. The study commenced in 1978 and had progressed 20 months at this stage. Fauna recorded within rehabilitated areas were compared to those in the adjacent upland jarrah forest (species lists provided). Succession of vertebrate fauna in rehabilitated areas was outlined on the basis of four vegetational stages: (1) new plantings with small trees (0-2 years); (2) understorey development with flower and seed production, some trees appearing (3-7 years); (3) tree development with suppressed understorey and leaf litter developed (5-20+ years); and (4) older trees with hollows and well developed bark, low understorey and leaf litter (>20 years). Species expected to return in each of the stages (feeding and/or breeding) are outlined, but prediction of faunal composition beyond Stage 2 becomes more conjectural.

Keals, N. and Majer, J.D. (1991). The conservation status of ant communities along the Wubin-Perenjori corridor. Pp 387-393 *in* Nature Conservation 2: The Role of Corridors. (Eds. D. A. Saunders and R. J. Hobbs). Surrey Beatty & Sons: Chipping Norton, New South Wales.

> Surveys and compares the ant fauna at 16 sites in roadside vegetation, three blocks of bushland and three cleared farm paddocks in Western Australia. The diversity of ants on roadsides without native vegetation was similar to that in cleared farmland. Richness of ants was still low in narrow (5 m) roadside vegetation, but in wide (20 m) roadsides it was generally comparable to that in bushland. The composition of ant functional groups also differed with width and condition of roadside vegetation.

Kentish, K.M. (1983). Mine Rehabilitation: A Study of Revegetation and Fauna Return at Anglesea (1980-82). Unpublished MSc thesis, School of Sciences, Deakin University.

> Studied the vegetation and faunal communities of an open-cut brown coal mining lease at Anglesea, Victoria. Unmined and rehabilitating areas of the minesite were surveyed to assess the extent to which communities re-establish on mined areas. Nine small mammal species were recorded on the minesite; four were recorded in the rehabilitating area. The abundance and ecology of three species – House Mouse *Mus musculus,* Swamp Rat *Rattus lutreolus* and New Holland Mouse *Pseudomys novaehollindae* were investigated. Additional surveys recorded 33 species of ant on the minesite. Concluded that faunal return on rehabilitated mined lands is determined by a combination of factors including: management of habitats adjacent to rehabilitation areas (source of potential colonisers); access between unmined and rehabilitating habitats; and type of habitat developing on rehabilitated areas (ability to fulfil needs of food and shelter). Rehabilitation practices should provide a similar diversity of habitats as was present in the original vegetation. Monitoring of habitat on rehabilitated mined lands should be an integral part of rehabilitation programs.

King, G. (1993). The need for trees on farms. Pp 11 *in* Agroforestry: Trees for Productive Farming. (Ed. D. Race). Agmedia: Melbourne.

> Briefly outlines the benefits of trees on farms including improved agricultural production, land protection and marketable timber products (agroforestry).

Kitchener, D. J., Chapman, A. Dell, J., Muir, B.G. and Palmer, M. (1980). Lizard assemblage and reserve size and structure in the Western Australian wheatbelt - some implications for conservation. *Biological Conservation* **18**: 179-207.

> Reptiles were surveyed in 23 reserves in the Western Australian wheatbelt to evaluate the adequacy of the reserve system. Species richness-area relationships for wheatbelt reserves were similar to the most comparable continental island lizard faunas. The number of vegetation associations was the best single predictor of species richness in reserves; other variables, including area, did not explain further variation. Although small reserves are valuable, suggests that 1500 ha is an optimum size. Woodland vegetation formations are particularly important for lizards.

Kitchener, D. J., Chapman, A., Muir, B.G. and Palmer, M. (1980). The conservation value for mammals of reserves in the Western Australian wheatbelt. *Biological Conservation* **18**: 179-207.

Surveys of mammals (excluding bats) were carried out on 23 reserves in the wheatbelt of Western Australia. Reserve area was the most significant predictor of mammal species richness accounting for 72% of variation. It is suggested that a reserve area of about 40,000 ha is required to conserve the regional assemblage of mammals likely to persist under moderate levels of anthropogenic disturbance. Reserves should have large areas of major vegetation formations. Species that have become extinct are believed to be those unable to cope with alteration in environmental patchiness caused by changes in pattern of fires from European occupation.

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

Species richness of birds in 22 reserves in the wheatbelt of Western Australia was surveyed and modelled in relation to reserve size, isolation and vegetation characteristics. Reserve size was the most important variable, and together with plant species richness accounted for 82% of the variation in bird species richness. Models for different subsets of birds were also developed, and for some of these vegetation attributes were more important than area. The species-area relationship for resident habitat-specific passerines was similar to that for island land-bird faunas, and it is suggested that these species may perceive the reserves as islands. Woodland vegetation formation was particularly important to both resident and transient species.

Kotzageorgis, G. C. and C. F. Mason (1997). Small mammal populations in relation to hedgerow structure in an arable landscape. *Journal of Zoology(*London) **242**(3): 425-434.

Examined the ecology of small mammals in farmland hedgerows of Essex, eastern England. Eight species of small mammals were captured; four species comprised 97% of captures. The characteristics of hedgerows important in maintaining populations of these four species were investigated. Three species were influenced by different characteristics – Bank Voles *Clethrionomys glareolus* by ground cover, Yellow-necked Mice *Apodemus flavicollis* by hedgerow condition (lack of gaps), and Common Shrews *Sorex araneus* by adjacent permanent water. The most abundant species (Wood Mice *A. sylvaticus*) was little influenced by hedgerow characteristics. Concludes that hedgerows are important for maintaining small mammal communities within arable land. They may provide permanent or sporadic habitat, or be used as corridors for dispersal between woodland fragments.

Krockenberger, M. (1998). Falling down: land clearing in Australia. *Habitat Australia* **26**: 13-21.

Lack, P.C. (1988). Hedge intersections and breeding bird distributions in farmland. *Bird Study* **35**: 133-136.

Based on data from a Common Bird Census (CBC) conducted on British farmland, the total number of birds recorded near to intersections of hedges (T-junctions) was 1.7 times higher than the number recorded along the same total length of straight hedge. Twelve bird species were recorded on eight or more of the farms; the main analysis was restricted to these. Of these, five species independently showed a significant preference for intersections. Possible reasons for this and implications for hedge removal are discussed.

Lambeck, R.J. (1997). Focal species: a multi-species umbrella for nature conservation. *Conservation Biology* **11**: 849-856.

Presents a multi-species approach to defining attributes to meet the needs of the biota in a landscape. The approach involves selection of species that will encapsulate the needs of other species. Focal species are identified as those most vulnerable to a particular category of threatening process. Minimum requirements of patch area, length, width and structure of corridors, levels of critical resources, and rate or intensity of threatening processes identified for those focal species form management guidelines for conserving all biota. However, this process only identifies design and management criteria to be applied to a landscape, not the area over which it must be applied in order to ensure viable populations. The minimum requirements could be used to identify a threshold in landscape quality below which retention of components of the biota is unlikely. These thresholds provide a goal for restoration, and, alternatively, if landscapes are being dismantled, a minimum level before viability is threatened. Monitoring of management actions is needed to test the assumption that providing for focal species will also protect all non-focal species.

Lambeck, R.J. (1999). Landscape Planning for Biodiversity Conservation in Agricultural Regions: A Case Study from the Wheatbelt of Western Australia. Biodiversity Technical Paper No. 2. Department of the Environment and Heritage: Canberra.

Presents a new procedure for identifying the compositional and management requirements for retaining biodiversity in agricultural landscapes. Using the Western Australian wheatbelt as a case study, this procedure adopts a 'focal species' approach to identify the minimum requirements of the flora and fauna in the landscape which form the basis for setting priorities for landscape planning and management. Also addresses the issues of integrating biodiversity conservation with other land uses.

Land and Water Resources Research and Development Corporation (1999). LWRRDC Home Page. Available URL: http://www.lwrrdc.gov.au

Laurance, W. F. (1991). Ecological correlates of extinction proneness in Australian tropical rain forest mammals. *Conservation Biology* **5**.

Data from studies on the relative occurrence of mammals in rainforest fragments in north Queensland, Australia, were used to investigate the factors influencing the vulnerability of species to habitat fragmentation. Seven ecological traits were investigated: body size, longevity, fecundity, trophic level, dietary specialisation, natural abundance in rainforest, and abundance in the surrounding modified habitat matrix. The most important determinant of vulnerability to extinction was the abundance of species in the modified matrix. Species that traverse or use resources in the matrix are able to persist in fragments, whereas those that avoid the disturbed habitats decline or disappear from fragments.

Lavorel, C. (1988). The Geometridae Lepidoptera of hedges in Val-de-Travers, Switzerland. [French]. *Bulletin de la Societe Neuchateloise des Sciences Naturelles* 111: 61-66.

Trapped and actively hunted Geometrids on six hedges of the Val-de-Travers, Switzerland. Captured 52 species in the hedges; 26 species were found to be living on trees and eight species living on plants of the border.

Leach, G. J. and Recher, H. F. (1993). Use of roadside remnants of softwood scrub vegetation by birds in south-eastern Queensland. *Wildlife Research* **20**: 233-249.

Surveyed the occurrence and diversity of birds in sections of remnant roadside vegetation in south-eastern Queensland. Roadside remnants provide useful habitat for a wide range of bird species.

Leary, D.E. (1995). An ecological assessment of the Monarto Revegetation Program. B.App.Sc.(Hons) Thesis. Department of Zoology, University of Adelaide: Adelaide.

Studied the avifauna of the Monarto region of south-eastern South Australia to determine whether bird communities can be restored by current revegetation programs. Within each of three habitat types (cleared, remnant and revegetation), bird species richness and abundance, food resources (nectar, and surface-active, flying and tree-dwelling invertebrates) and habitat characteristics were assessed. A total of 81 bird species and 24 invertebrate orders were recorded for the Monarto region. Of the invertebrates, 23 orders were detected in revegetation, 24 in native vegetation and 21 in agricultural land. Abundance of invertebrates was highest in agricultural land with more Coleoptera, Hymenoptera (ants) and Diptera than in either of the vegetated sites. Significantly fewer bird species were found in cleared agricultural land than in revegetated and remnant sites. Community composition varied between habitat types. A strong relationship between bird presence and abundance and structural characteristics was detected. Variation in bird distributions within revegetation were explained by food resources rather than floristics or structure (physiognomy), suggesting that birds are habitat generalists that occur wherever there are insects or nectar. Concludes that the Monarto Revegetation Program has clearly benefited the regional avifauna and that birds are good bioindicators for assessing the value of the revegetation.

Lefroy, E.C. and Hobbs, R.J. (1998). Agriculture as a mimic of natural ecosystems. Workshop report for the RIRDC/LWRRDC/FWPRDC Joint Venture Agroforestry Program, 2-9 September 1997. RIRDC Pub No. 98/66. Rural Industries Research and Development Corporation: Canberra.

Details outcomes of the workshop addressing agriculture as a mimic of natural ecosystems and presents a broad approach for the development of natural systems agriculture.

Lefroy, E.C., Hobbs, R.J. and Atkins, L.J. (1991). Revegetation Guide to the Central Wheatbelt. Department of Agriculture Western Australia: Perth.

Provides a guide for revegetating the central wheatbelt of Western Australia that includes a list of local plant species grouped according to soil types, an identification guide and description for each plant species, a list of bird species known to use the major vegetation types, and a summary of knowledge on revegetation methods. Information is included on obtaining and sowing seeds, and design and location of revegetation.

Lefroy, T., Hobbs, R.J. and Scheltma, M. (1993). Reconciling agriculture and nature conservation: towards a restoration strategy for the Western Australian wheatbelt. Pp 243-257 *in* Nature Conservation 3: Reconstruction of Fragmented Ecosystems: Global and Regional Perspectives. (Eds. D.A. Saunders, R.J. Hobbs and P.A. Ehrlich). Surrey Beatty and Sons: Chipping Norton, New South Wales.

Systematically describes the nature and extent of revegetation necessary to overcome land degradation in the wheatbelt of Western Australia. Focuses on restoration of basic ecosystem functions as a common element for achieving both conservation and improved production. Addresses the amount of vegetative cover the region needs to ensure its long-term health and potential economic values that may motivate such vegetation establishment. Suggests around 500 million to one billion trees and shrubs are required over the 15 million ha of cleared land. Concentrating revegetation into belts planted in relation to landform and aspect is most likely to achieve simultaneous production, land protection and conservation benefits. The economic and nature conservation values (actual and potential) of such a vegetation network, and the practicality of revegetation at this scale are discussed.

Lewis, T. (1969). The diversity of the insect fauna in a hedgerow and neighbouring fields. *Journal of Applied Ecology* **6**: 453-458.

Seventy-seven insect taxa (terrestrial and aerial) were found in a hedgerow and neighbouring field in Hertfordshire, England. A comparison of broad community structure showed: (1) differences in diversity between the two habitats; (2) the degree to which the insect fauna of neighbouring crops is enriched by the hedgerow, and (3) the local effect of hedgerows. Insect species diversity was greater in hedgerows than surrounding crops and pasture. However, diversity in these latter habitats was enriched by insects spreading from the hedgerow. Distances to which aerial insects spread over crops represented shelter zones produced by hedges; 3-10 times its height to leeward and 1-2 times to windward.

Limpens, H. J. G. A. and Kapteyn, K. (1989). Bats, their behaviour and linear landscape elements. *Myotis* **29**: 63-71.

Investigated the use of linear landscape elements (double lanes, hedges and canals) by bats in the Netherlands. Bats used linear features in several ways: (1) as a flight path only; (2) as a flight path as well as a feeding area; (3) as a flight path and feeding area en-route to preferred feeding areas; or (4) did not directly utilise linear elements. Use was related to bat species' size, sonar type and range, and general hunting area. Smaller bats, such as Daubenton's Bat *Myotis dubentoni*, detoured along hedgerows rather than cross open areas to reach their hunting habitat, whereas larger species were less restricted. Concludes that linear landscape elements are an important factor contributing to the ecological infrastructure for bats.

Loney, B. and Hobbs, R.J. (1991). Management of vegetation corridors: maintenance, rehabilitation and establishment. Pp 299-311 *in* Nature Conservation 2: The Role of Corridors. (Eds. D. A. Saunders and R. J. Hobbs). Surrey Beatty & Sons, Chipping Norton, New South Wales.

A review of management issues associated with vegetation corridors, recognizing that the management requirements for a corridor depend on its mode of origin and its function. Argues for an integrated approach to management involving planning, development, implementation, monitoring and evaluation at all stages. Important components of management are manipulation of internal corridor processes and the external influences on these. We need to maintain existing corridors, rehabilitate degraded corridors and establish new corridors.

Loyn, R. H. (1987). Effects of patch area and habitat on bird abundances, species numbers and tree health in fragmented Victorian forests. Pp 65-77 *in* Nature Conservation: The Role of Remnants of Native Vegetation. (Eds. D. A. Saunders, G. W. Arnold, A. A. Burbidge and A. J. M. Hopkins). Surrey Beatty and Sons: Chipping Norton, New South Wales.

Surveyed the occurrence and richness of birds in 59 remnants of native vegetation in Gippsland Victoria. Developed statistical models to explain the richness of different groupings of birds. Richness of forest-dependent birds was best explained by patch size, diversity of habitats and time since patch isolation. Small forest patches, which were typically grazed by stock and had open vegetation, were frequently dominated by Noisy Miners and few native forest birds were present. Discusses the role of Noisy Miners, their influence on small insectivorous birds, and the implications for tree health in farmland.

Lynch, J. F. and Saunders, D.A. (1991). Responses of bird species to habitat fragmentation in the wheatbelt of Western Australia: interiors, edges and corridors. Pp 143-158 *in* Nature Conservation 2: The Role of Corridors. (Eds. D. A.

Saunders and R. J. Hobbs). Surrey Beatty and Sons: Chipping Norton, New South Wales.

Compared the avifauna of roadside strips (corridors) with that of the edges and interiors of large patches of vegetation in the Western Australian wheatbelt. Of a total of 61 species of birds encountered during the surveys, 74% occurred in roadside vegetation, at least occasionally. Tendency of species to occur in corridors was correlated with their tendency to occur along the edges of large patches. Most passerines that depend on native vegetation are more common in reserve interiors than in road verges, but the reverse is true for species that nest and shelter in vegetation but mainly feed in paddocks. Some species show seasonal shifts in use of roadside corridors. The avifauna of the region now differs from that present prior to widespread clearing. A number of species now rare or extinct are widespread and common in the more vegetated country of the western Goldfields.

Lyngby, J.E. and Nielsen, H.B. (1981). The spatial distribution of carabids (Coleoptera, Carabidae) in relation to a shelterbelt. *Entomologiske Meddelelser* **48**(3): 133-140.

Investigated the effect of shelterbelts on the spatial distribution of carabids in an alfalfa field near Aarhus, Denmark. A total of 5962 carabids, representing 39 species, were caught and grouped according to spatial distribution patterns: those associated with (a) the shelterbelt, (b) the border of shelterbelt, (c) the field, and (d) those with variable spatial distribution. Diversity was highest in the middle of the shelterbelt and declined significantly with distance. Spatial distributions and the reasons for these are discussed.

McIntyre, S. and Hobbs, R. (in press). Human impacts on landscapes: matrix condition and management priorities. *In* Nature Conservation 5: Nature Conservation in Production Landscapes. (Eds. J. Craig, N. Mitchell and D.A. Saunders).

Macdonald, D.W. and Johnson, P.J. (1995). The relationship between bird distribution and the botanical and structural characteristics of hedges. *Journal of Applied Ecology* **32**(2): 492-505.

Examined the relationship between structural and botanical characteristics and associated bird populations in 266 hedgerows on five Oxfordshire farms, England. Bird-rich hedges tended to be tall and with more species of shrubs. Bird density was positively correlated with hedgerow height, number of mature trees and presence of garden habitat close to the hedgerow. Gaps in the hedgerow had a significant negative effect on abundance of birds. Implications of these results for practical management for bird conservation are discussed. The best hedgerows for bird diversity and abundance of most common farmland species are large, mature, and support a variety of woody species.

Majer, J.D. (1983). Recolonisation by ants in rehabilitated open-cut mines in Northern Australia. *Reclamation and Revegetation Research* **2**: 279-298.

Describes an investigation of ant colonisation in rehabilitated manganese mines at Groote Eylandt, Northern Territory, and bauxite mines at Gove, Northern Territory, and Weipa, North Queensland. Ant colonisation rates were not statistically different between sites. Species richness increased rapidly during the first 1.5 years and levelled off to values similar to forest control plots between 3.5 and 7.5 years following rehabilitation. Whilst density and richness approached that of the forest ant community after 7.5 years, species composition remained different. Complete restoration of the forest fauna in mined areas will take much longer than 7.5 years.

Majer, J.D. (1985). Recolonisation by ants of rehabilitated mineral sand mines on North Stradbroke Island, Queensland, with particular reference to seed removal. *Australian Journal of Ecology* **10**: 31-48,

Surveyed the ant fauna of 12 sand-mined plots of varying rehabilitation age, and three undisturbed vegetation controls on North Stradbroke Island, Queensland. A total of 64 ant species was collected, of which 44 had colonised rehabilitated sites. Recolonisation by ant species occurred rapidly in plots up to 6 years old, with species richness and diversity approaching that of control plots. However, composition of the ant fauna differed between mined and unmined sites with few species shared. Ant succession proceeded more slowly in older sites where the tramp ant *Pheidole megacephala* dominated the fauna. Older sites had lower species richness than younger sites. Larger amounts of litter, less bare ground and longer time since rehabilitation were most highly correlated with ant species richness. Although unable to put a realistic scale on ecosystem recovery, it was considered to be longer than 17 years

Majer, D.J. (ed.) (1989). Animals in Primary Succession: the Role of Fauna in Reclaimed Lands. Cambridge University Press: Cambridge.

A compilation of chapters by various authors addressing the ability for animals to recolonise reclaimed lands. The book is divided into six parts: (1) an introductory chapter which outlines types of land-use and means by which fauna can influence reclamation of these lands; (2) a series of five chapters which examine how animals influence various facets of developing ecosystems on reclaimed land; (3) addresses the more practical aspects of fauna return in a series of six chapters; (4) a selection of five case studies from various countries to reinforce the preceeding chapters; (5) a synthesis of the information presented throughout the book; and (6) a bibliography of fauna studies in reclaimed lands.

Majer, J.D. (1989). Long-term colonisation of fauna in reclaimed land. Pp 143-174 *in* Animals in Primary Succession: the Role of Fauna in Reclaimed Lands. (Ed. D.J. Majer). Cambridge University Press: Cambridge.

In reviewing faunal recolonisation in reclaimed lands, this chapter concludes that recolonisation in the short and long-term is influenced by a wide range of factors including presence of suitable colonising species in the vicinity, the order of colonisation (succession), and the floristic and structural nature of the surrounding vegetation. Wide differences exist between the rate and patterns of animal recolonisation in different regions and differences may exist between taxa within the region. The need for more baseline surveys of the characteristics of fauna in areas about to be disturbed and for carefully monitored long-term studies in a variety of vegetation and climatic zones is identified.

Majer, J.D. (1990). Rehabilitation of disturbed land: long-term prospects for the recolonisation of fauna. *Proceedings of the Ecological Society of Australia* **16**: 509-519.

Reviews factors which influence faunal recolonisation of disturbed land including type of pre-disturbance habitat, size and isolation of rehabilitation, habitat changes (physical and botanical) during rehabilitation maturation, and competition between colonising animals. Recovery at the levels of community and ecosystem are addressed. Concludes that wide differences exist between the rate and patterns of animal recolonisation in different regions and between taxa within a particular region. Identifies a need for faunal surveys of areas about to be disturbed to facilitate an understanding of factors influencing their ability to recolonise rehabilitated land. There is also a need for carefully monitored long-term studies in rehabilitated lands using identical techniques to enable comparisons between areas and generalisations for particular climatic and vegetation types.

Majer, J.D., Day, J.E., Kabay, E.D. and Perriman, W.S. (1984). Recolonisation by ants in bauxite mines rehabilitated by a number of different methods. *Journal of Applied Ecology* **21**: 355-375.

Forty-two species of ants were found in rehabilitated bauxite mined areas in Western Australia. The return of a highly diverse ant fauna to rehabilitated bauxite mines has been attributed to high plant species richness and diversity, high plant cover, rehabilitation age, thick and widespread litter cover, and presence of some logs or standing wood. The relevance of findings to improvement of rehabilitation practices for Jarrah forest species not yet present within the rehabilitated areas is discussed.

Marcar, N., Crawford, D., Leppert, P., Jovanovic, T., Floyd, R. and Farrow, R. (1995). Trees for Saltland: A Guide to Selecting Native Species for Australia. CSIRO Press: Melbourne.

Provides a reference to assist decisions about which Australian native tree species can be planted on salt-affected and waterlogged land. Outlines the principles of growing trees on salt-affected land including how trees deal with salinity, the susceptibility of tree species to insect attack, and where and how to establish trees. Provides descriptions of 60 species for use on salted land – 30 in detail and 30 in summary form.

Margules, C. R. and Milkovits G.A. (1994). Contrasting effects of habitat fragmentation on the scorpion *Cercophonius squama* and an amphipod. *Ecology* **75**: 2033-2042.

Populations of a scorpion and an amphipod were monitored for 3 years before and 5 years after experimental fragmentation in south-eastern Australia. Abundance of scorpions did not change significantly and there was no effect of fragment size. In contrast, the amphipod decreased markedly in fragments compared to controls, especially on smaller fragments. It is suggested that the amphipod is more susceptible than the scorpion species to changed ecological conditions brought about by fragmentation. These results highlight the need to consider species responses – it is difficult to generalize about responses to fragmentation.

Marshall, C.J. (1990). Control of erosion. Pp 369-376 *in* Trees for Rural Australia. (Ed. K.W. Cremer). Inkata Press: Melbourne.

Outlines the role of trees and selection of species for controlling or preventing various forms of soil erosion.

Martin, T.E. (1980). Diversity and abundance of spring migratory birds using habitat islands on the Great Plains. *Condor* **82**: 430-439.

Examined the relationships of area with numbers of species and individuals of spring migrants for 69 shelterbelts in eastern South Dakota, USA. Area was found to be more important in determining abundance and number of species than either diversity of plant species or isolation of the shelterbelts (forest islands).

Meijer, J. (1989). Sixteen years of fauna invasion and succession in the Lauwerszeepolder. Pp 339-369 *in* Animals in Primary Succession: The Role of Fauna in Reclaimed Lands. (Ed. by J.D. Majer). Cambridge University Press: Cambridge).

Describes 16 years of arthropod invasion of land that was reclaimed from the sea in the Netherlands. The important factors which govern the rate and type of succession are identified as salinity and dispersal attributes of species.

Mineau, P. and McLaughlin, A. (1996). Conservation of biodiversity within Canadian agricultural landscapes: integrating habitat for wildlife. *Journal of Agricultural and Environmental Ethics* **9**(2): 93-113.

Reviews the 'current' (1996) literature addressing the potential for non-crop areas within agricultural landscapes to be reservoirs of agronomically beneficial organisms including plants, invertebrates and vertebrate species (namely birds). Discusses: the agricultural benefits from increased biodiversity within arable lands for various species groups; the ability for herbaceous field margins, hedgerows and shelterbelts to provide habitat for beneficial organisms; managing habitat for conservation of biodiversity; agricultural policies and programs and conservation of biodiversity; and conflicts between agriculture and wildlife, which are impediments to the creation and management of wildlife habitat.

Mitchell, D.J., Fullen, M.A. *et al.* (1998). Sustainability of reclaimed desertified land in Ningxia, China. *Journal of Arid Environments* **39**(2): 239-251.

Outlines Chinese initiatives to combat desertification, a severe environmental problem in north-central China, where deserts are estimated to be expanding at a rate of 2100 km^2 per year. Provides examples to illustrate what is achievable, but desertification rates unfortunately continue to exceed reclamation rates.

Moore, R. (1992). Integrating wood production into Australian farming systems. *Agroforestry Systems.* 20: 167-186.

Discusses the potential for Australian farmers to integrate wood production with planting to improve productivity, and overcome problems such as salinity and wind erosion. Addresses types of wood products, management of multipurpose plantings, economic aspects, harvesting and processing wood, encouraging new wood industries and incentives for farmers to produce wood.

Morgan, K.A. and Gates, J.E. (1982). Bird population patterns in forest edge and strip vegetation at Remington Farms, Maryland. *Journal of Wildlife Management* **46**(4): 933-944.

Sampled and compared the richness, abundance and diversity of bird species for six management situations – open forest edges, forest edges with a rose hedgerow, hedgerow waterways, grass waterways, and rose hedgerows with unmown or mown grass borders – in agricultural land, Maryland, USA. Seasonal variations in the use of edge and strip vegetation were found with bird abundance generally increasing in spring/summer. Forest edge hedgerows had higher species diversity, abundance and richness than open forest edges; hedgerow waterways were higher than grass waterways, and hedgerows with unmown or mown grass border exhibited little difference. Mixed-habitat or edge species were detected in the forest edge hedgerows but were absent at open forest edges. Hedgerows in intensive agricultural areas may provide the majority of habitat for wildlife, increase habitat heterogeneity, provide travel corridors and foraging areas.

Morris, J.D. and Jenken, J.J. (1990). Trees in salinity control. Pp 357-366 *in* Trees for Rural Australia. (Ed. K.W. Cremer). Inkata Press: Melbourne.

Discusses the causes and effects of salinity and how trees can be used to treat the problem.

Mues, C., Roper, H. and Ockerby, J. (1994). Survey of Landcare and Land Management Practices: 1992-93. ABARE Research Report 94.6: Canberra.

Presents the results of a survey of Landcare and land management practices conducted during the 1992-93 financial year on over 1800 farms chosen to be representative of the broadacre and dairy industries in Australia. The survey was commissioned as part of the monitoring, evaluation and review process of the Decade of Landcare initiative. It aimed to collect information on expenditure on land care related works and the use of tax concessions for works of this nature, Landcare membership, farm planning, land degradation problems and farm practices, with each issue addressed in a separate section.

Mues, C., Chapman, L. and Van Hilst, R. (1998). Promoting Improved Land Management Practices on Australian Farms: A Survey of Landcare and Land Management Related Programs. ABARE Research Report 98.4: Canberra.

Presents the results of a 1995-96 survey of Landcare and land management practices which build on data collected in the 1992-93 survey which covered many of the same issues. This most recent survey was designed to collect information on the skills and education of land managers, participation in Landcare activities, and the extent of implementation of best management practices.

Munteanu, D. (1990). Bird populations in the forest shelterbelts of Ceanu Mare Transylvanina Plain. [French]. *Studia Universitatis Babes-Bolyai Biologia* **35**(1): 18-21.

Censused breeding birds in forest shelterbelts near Ceanu Mare (Cluj county, Romania) in May-June 1982. The features of this recent man-made habit, which includes 27 ha of trees and bushes, are described. Twenty-one breeding bird species were recorded; the most characteristic species usually inhabit the ecotone wood-plain. The absence of birds which feed on soil fauna was noted (pronounced paucity of soil fauna), as was the scarcity of hole-nesting species (lack of appropriate nest building sites). Changes are likely in the bird community as the habitat changes with time.

Nadolny, C. (1991). Species and provenance selection for revegetation. *Growback* 1: 25-29.

The philosophies of species selection are discussed, and techniques for collecting seed and choosing the right plant for a site are outlined. Rural dieback and species selection is also briefly addressed.

Natural Heritage Trust (1999). Natural Heritage Trust Home Page. Available URL: http://www.nht.gov.au.

Nicoll, C.L. and Dobbie, M.J. (1996). The CSIRO National Farm Tree Survey. Technical Memorandum 96.26. CSIRO Division of Water Resources: Canberra.

Presents the results of a national tree survey conducted in 1995 by CSIRO documenting landholder's observations of trees planted for land degradation control.

Nichols, O.G. and Bamford, M.J. (1985). Reptile and frog utilisation of rehabilitated bauxite minesites and dieback-affected sites in Western Australia's Jarrah *Eucalyptus marginata* forest. *Biological Conservation* **34**: 227-249.

Discusses the extent to which reptile and frog species utilise revegetated bauxite minesites compared with unmined healthy and dieback-affected Jarrah forest areas. Four to six-year-old revegetated sites supported similar numbers (70%) of herptile species as unmined upland Jarrah forest sites, although at densities comparable to poorer quality forest. The number and abundance of species utilising revegetated sites directly related to microhabitat requirements of each species. Changes in habitat components over time are discussed in relation to their influence on particular species. Leaf litter, understorey cover, log abundance, and availability of open foraging space influence reptile density in revegetated sites. While herpetofauna were recorded using rehabilitated bauxite minesites, it is emphasised that species need to establish self-regenerating populations before rehabilitated sites can be regarded as providing suitable habitat.

Nichols, O.G. and Bunn, S. (1980). Termite Utilisation of Rehabilitated Bauxite Mine Sites. Alcoa of Australia Ltd. Environmental Research Bulletin No. 9.

Investigated the degree to which termites utilise rehabilitated areas. Ten species of termite were found in rehabilitated areas while three species were not. Important factors affecting the abundance of termites on rehabilitated bauxite minesites included litter, small logs and other wood materials.

Nichols, O.G. and Burrows, R. (1985). Recolonisation of revegetated bauxite mine sites by predatory invertebrates. *Forest Ecology and Management* **10**: 49-64.

Discusses the utilisation of revegetated bauxite minesites by predatory insects. Predatory invertebrates play an important ecological role by assisting with the control of pest outbreaks. Additionally, larger invertebrates provide food for vertebrates such as reptiles, birds and mammals. Their presence may also indicate an abundance of other invertebrates as a food source. Generally, leaf litter, logs and the diversity and structure of understorey trees and shrubs influence the density and diversity of predatory invertebrates. "Better" rehabilitated areas compared favourably with healthy forest. Concludes that rehabilitated mined areas will not form an ecological barrier to movement of predatory invertebrates.

Nichols, O.G. and Watkins, D. (1984). Bird utilisation of rehabilitated bauxite minesites in Western Australia. *Biological Conservation* **30**: 109-131.

Discusses the extent to which bird species utilise bauxite minesites revegetated by a number of techniques compared with healthy and dieback-affected Jarrah forest. Most bird species of Jarrah forests utilised revegetated minesites for feeding, resting or breeding. Areas as young as 4-5 years old which were seeded with understorey species or laid with fresh topsoil to promote regeneration of diverse understorey plants supported bird species diversities, densities and abundances similar to those of unmined healthy forests. In contrast, areas with very little understorey such as those rehabilitated with trees (pines or eucalypts) or forest areas affected by dieback supported limited populations of birds compared with healthy forests. Some species were not found in rehabilitated areas. Potential reasons for their absence were considered including availability of insect populations, hollows, mature trees, and flowering eucalypts. The relevance of findings to improvement of rehabilitation practices is discussed.

Nichols, O.G., Wykes, B.J. and Majer, J.D. (1989). The return of vertebrate and invertebrate fauna to bauxite mined areas in south-western Australia. Pp 397-422 *in* Animals in Primary Succession: The Role of Fauna in Reclaimed Lands. (Ed. by J.D. Majer). Cambridge University Press: Cambridge.

Provides a good review of research into the return of fauna to rehabilitated bauxite mined areas in Western Australia.

Norton, D. A., Hobbs, R. J. and Atkins, L. (1995). Fragmentation, disturbance, and plant distribution: mistletoes in woodland remnants in the Western Australian wheatbelt. *Conservation Biology* **9**: 426-438.

Examined the distribution of the mistletoe *Amyema miquelii* in woodland fragments and sections of roadside vegetation dominated by Salmon Gum *Eucalyptus salmonophloia* in the Western Australian wheatbelt. Large fragments were more likely to have mistletoes than small fragments, and fragments subject to grazing by stock had no mistletoes. Mistletoes were extremely scarce on roadsides, although these are often considered good habitat for mistletoes. Either fruit-dispersing birds do not use these corridors or do not stay long enough to deposit seed. Illustrates the difficulty of predicting the effects of fragmentation for a species (and process) which is patchy in the pre-fragmentation landscape, and where disturbance processes confound the fragmentation process.

Oates, N. (ed.) (1995). Putting Back the Bush: The Role of Trees in Sustainable Agriculture – Workbook 1. Greening Australia Ltd., Rural Industries Research and Development Corporation, and the Land and Water Research and Development Corporation: Canberra.

First in a three-part series on 'The Role of Trees in Sustainable Agriculture' developed from papers presented to a National Conference, the first to bring together research highlighting the importance of trees on farms. This workbook highlights the need for conservation and establishment of vegetation for sustainable land management. It looks at how trees prevent wind and water erosion, and control salinity, and explores how corridors of vegetation may offer a means of movement for native wildlife thereby enabling biodiversity to be maintained. It also presents the technique of whole farm planning as a tool to integrate revegetation programs into farming practices.
Two other workbooks in this series are:

- Making Farm Trees Pay: The Role of Trees in Sustainable Agriculture – Workbook 2. Guest editor Rowan Reid
- A Haven from Storm and Drought: The Role of Trees in Sustainable Agriculture – Workbook 3. Guest editors Steve Burke and Allan Wilson

Oates, N. and Clarke, B. (1987). Tree$ for the Back Paddock. Goddard and Dobson: Melbourne.

Describes the main principles involved in site selection, ground preparation, successful planting and on-going management of farm trees. Illustrates how to develop a revegetation strategy for properties and advocates commercial values of farm trees. Chapters include: the importance of soils; farm productivity and trees; whole farm planning and site selection for trees; selecting the species to plant; tree planting layout and design, preparing the site; raising seedlings and natural regeneration; planting trees; early maintenance; management and protection; measurements, yields, utilisation and marketing; financial and legal aspects; and tree growing assistance.

Office of the Commissioner for the Environment. (1991). Agriculture and Victoria's Environment. Office of the Commissioner for the Environment: Victoria.

As the first comprehensive review of Victorian agriculture and its relationship to the environment, this report describes the development of agriculture in the State, considers past and current agricultural practices and environmental impacts, reviews research studies, describes land protection programs and provides recommendations for future monitoring.

Ogilvie, R.T. and Furman, T. (1959). Effect of vegetation cover of fencerows on small mammal populations. *Ecology* **40**: 140-141.

This investigation was conducted in farmlands of Whitman County, Washington, USA, to investigate differences in small mammal populations in three types of fencerows of varying vegetation cover (shrubby, weedy and virtually bare). The relative abundance of four species of mammals in each vegetation types is discussed and related to known ecological requirements.

O'Neill, G. (1999) . Renaissance on Lanark. *Wingspan* (Supplement) **9**: 1-16.

Outlines the return of birds to 'Lanark', a grazing property owned by John and Cicely Fenton in Victoria's Western District. Dedicated to returning trees to the land since the 1960's, the Fenton's have planted over 80,000 trees for habitat, farm forestry plots, swamps or shelterbelts. Since 1954, Murray Gunn, a naturalist from nearby Hamilton, has recorded the birds present on the property. The revegetation efforts have assisted the return of almost the entire suite of bird species that once inhabited the region's native woodlands and wetlands. By 1996, 155 species of native birds had been recorded on 'Lanark' compared with 39 species in 1956.

Osborne, P. (1984). Bird numbers and habitat characteristics in farmland hedgerows. *Journal of Applied Ecology* **21**: 63-82.

Presents the results of a statistical analysis of the relationships between bird numbers and characteristics of 42 hedges on a farm in Dorset, England. Bird rich hedges were characterised by a large basal area, many tree species, some dead timber and being in close proximity to scrub habitats.

Paoletti, M.G., Boscolo, P. *et al.* (1997). Beneficial insects in fields surrounded by hedgerows in north eastern Italy. *Biological Agricultural and Horticulture* 15(1-4): 311-323.

Investigated the distribution of invertebrates in wheat and alfalfa fields encircled by hedges in the low plains of north-eastern Italy. The number of predator-parasitoid individuals and species found in the hedges was higher than in the centre of the field. The wheat-field margins had higher catches of predator-parasitoids than the field centre while catches were similar in both the alfalfa field centres and margins; all were lower than in the hedgerows.

Parish, T., Lakhani, K.H. and Sparks, T.H. (1994). Modelling the relationship between bird population variables and hedgerow and other field margin attributes. I. Species richness of winter, summer and breeding birds. *Journal of Applied Ecology* **31**: 764-775.

Surveyed field boundaries at two sites in eastern England to determine how farming practices, dimensions of hedges and other components of the boundaries affect birds. Bird species richness was positively correlated with the size of hedge, number and height of trees, and adjacent permanent pasture. Management options for field boundaries to benefit birds are presented.

Parish, T., Lakhani, K.H. and Sparks, T.H. (1995). Modelling the relationship between bird population variables and hedgerow, and other field margin attributes. II. Abundance of individual species and of groups of similar species. *Journal of Applied Ecology* **32**: 362-371.

Surveyed field boundaries at two sites in eastern England to determine how farming practices, dimensions of hedges and other components of the boundaries affect birds. Abundance of many bird species was influenced by surrounding land use and vegetation attributes (tree height and number, hedgerow length, height and width). The influence of these factors varied between species; modelling assisted an examination of the habitat requirements of particular species. General management prescriptions are discussed and an evaluation of the results from both studies is presented.

Pearce, F. (1994). Greening the heart of England. *New Scientist* **September**: 30-35.

Outlines and discusses an initiative to recreate the forest that once covered 80 percent of the British lowlands. However, plans for a publicly owned company to run Britain's National Forest in the Midlands has sparked concerns that the initiative is a guise for lucrative but environmentally destructive activities.

Petrides, G.A. (1942). Relation of hedgerows in winter to wildlife in central New York. *Journal of Wildlife Management* **6**(4): 261-280.

Presents results of a study conducted at Ithaca, central New York, USA, in 1939-40. Field observations recorded 93 bird species in hedgerows about Ithaca in the years prior to this study; 17 species were considered 'typical' hedgerow birds, 12 of which were sparrows. During this study 15 species of birds were observed feeding, nesting or resting in hedgerows and 12 species of mammals inhabited hedgerows. Recommendations for management of hedgerows are made.

Pollard, E. and J. Relton (1970). Hedges. V. A study of small mammals in hedges and cultivated fields. *Journal of Applied Ecology* **7**: 549-557.

Presents results of an introductory study on small mammals in farmland hedges in Huntingdonshire, UK. The main aim was to study the distribution of small mammals in farmland habitats. Ten species were recorded in farmland hedges. Habitat utilisation differed between these small mammal species, for example: the Bank Vole was almost entirely restricted to hedges and probably dependent on woody or other dense cover, while the Field Mouse ranged widely between hedge and field habitats.

Pollard, E. Hooper, M.D. and Moore, N.W. (1974). Hedges. Collins: London.

Includes four chapters on faunal groups (birds, mammals, reptiles and amphibians, invertebrates) and their use of hedges in England. Reviews what is known from other studies as well as from their own work.

Presst, I. (1971). An ecological study of the viper in southern Britain. *Journal of Zoology, London* 164: 373-418.

Presents the results of a general ecological study of the Northern Viper (adder) *Vipera berus* in Dorset, southern Britain.

Prinsley, R. (ed.) (1991). The Role of Trees in Sustainable Agriculture: A National Conference. Proceedings. Bureau of Rural Resources: Canberra.

A compilation of papers presented at a national conference 'The Role of Trees in Sustainable Agriculture', held 30 September to 3 October 1991 at Albury, New South Wales. This was the first conference to bring together research highlighting the importance of trees on farms. These proceedings include national and state reviews of salinity, shelter and erosion, native vegetation, timber, fodder, and other minor forest products, and other workshop papers and notes. Three workbooks were produced in 1995 based on these proceedings:

- Workbook 1 - Putting Back the Bush: The Role of Trees in Sustainable Agriculture. Guest editor Nan Oates. Discusses the need for conservation and establishment of vegetation for sustainable land management.
- Workbook 2 – Making Farm Trees Pay: The Role of Trees in Sustainable Agriculture. Guest editor Rowan Reid. Examines how commercial tree products can become an integral component of farm productivity.
- Workbook 3 - A Haven from Storm and Drought: The Role of Trees in Sustainable Agriculture. Guest editors Steve Burke and Allan Wilson. Discusses the role of trees in improving farm productivity such as providing shelter and shade for crops and livestock and as an alternative source of fodder for livestock.

Prinsley, R.T. (1992). The role of trees in sustainable agriculture – an overview. *Agroforestry Systems* **20**: 87-115.

Examines the potential benefits of agroforestry for rehabilitating degraded land, improving agricultural productivity, producing timber, and contributing to diversification of, and increases in, farm income, by using information available from research.

Race, D. (ed.) (1993). Agroforestry: Trees for Productive Farming. Agmedia: East Melbourne.

Outlines the benefits, techniques, species and management of agroforestry in south-eastern Australia in a compilation of independently authored chapters. Includes information on: benefits of trees including fire protection, wildlife habitat, shelter and shade, and timber products; design to achieve these benefits; species selection for agroforestry; and management techniques.

Recher, H.F. (1989). Colonisation of reclaimed land by animals: an ecologist's overview. Pp 441-448 *in* Animals in Primary Succession: The Role of Fauna in Reclaimed Lands. (Ed. J.D. Majer). Cambridge University Press: Cambridge.

Summarises the role of fauna in land reclamation, and patterns of fauna establishment (colonisation and succession), and presents concluding principles including critical actions for facilitating faunal recolonisation of rehabilitated land.

Recher, H.F. (1991). The conservation and management of eucalypt forest birds: resource requirements for nesting and foraging. Pp 25-34 *in* Conservation of Australia's Forest Fauna. (Ed. D. Lunney). Royal Zoological Society of New South Wales.

Outlines the range of resources used by forest birds for nesting and foraging, including particular resources (such as spiders web, lichens) and foraging substrates used by selected species. Emphasizes that forest management to retain biodiversity is complex, and critical resources include more than tree hollows.

Recher, H.F. (1993). The loss of biodiversity and landscape restoration: conservation, management, survival: an Australian perspective. Pp 141-151 *in* Nature Conservation 3: Reconstruction of Fragmented Ecosystems: Global and Regional Perspectives. (Eds. D.A. Saunders, R.J. Hobbs and P.R. Ehrlich). Surrey Beatty and Sons: Chipping Norton.

Discusses the loss of biodiversity in Australia and the issue of landscape restoration. Includes a definition of biodiversity, and overview of the state of the Australian biota, discusses whether restoring biodiversity is necessary and presents ecological principles for rehabilitating degraded landscapes.

Recher, H.F. and Lim, L. (1990). A review of current ideas of the extinction, conservation and management of Australia's terrestrial vertebrate fauna. *Proceedings of the Ecological Society of Australia* **16**: 427-440.

Reviews the status of Australia's terrestrial biota. Outlines the decline and extinction of some species and increases in the abundance of others. Discusses patterns of change, possible causes of this change, and the future of Australia's terrestrial fauna.

Recher, H. F. and Serventy, D. L. (1991). Long term changes in the relative abundances of birds in Kings Park, Perth, Western Australia. *Conservation Biology* **5**: 90-102.

Compares the bird fauna of Kings Park, Perth, Western Australia, an isolated bushland reserve of 300 ha, based on surveys carried out in 1928-9 and in 1986. Over the 60 year period, 20% of species present in 1928-9 have become locally extinct and a further 11% have declined in abundance. Discusses the reasons for, and implications of, such change within an isolated habitat remnant.

Reid, R. (ed) (1995). Making Farm Trees Pay: The Role of Trees in Sustainable Agriculture – Workbook 2. Greening Australia Ltd., Rural Industries Research and Development Corporation, and the Land and Water Research and Development Corporation: Canberra.

Second in a three-part series on 'The Role of Trees in Sustainable Agriculture' developed from papers presented to a National Conference, the first to bring together research highlighting the importance of trees on farms. This workbook reviews opportunities for commercial tree crops and timber production when considering trees for land degradation control, shade and shelter for stock and crops or as a means of diversifying farm income. Includes sections on choosing timber products to pursue, incorporating timber production into a farm plan, a guide to low and high value timber products, and managing trees for timber. Provides case studies to illustrate the information provided.
Two other workbooks in this series are:

- Putting Back the Bush: The Role of Trees in Sustainable Agriculture – Workbook 1. Guest editor Nan Oates
- A Haven from Storm and Drought: The Role of Trees in Sustainable Agriculture – Workbook 3. Guest editors Steve Burke and Allan Wilson

Reid, R. and Bird, P.R. (1990). Shade and shelter. Pp 319-335 *in* Trees for Rural Australia. (Ed. K.W. Cremer). Inkata Press: Melbourne.

Discusses research into the impact of heat and cold stress on livestock and crops, the benefits of shelter for crop and livestock production, and designing to achieve these benefits.

Reid, R. and Wilson, G. (1986). Agroforestry in Australia and New Zealand. Goddard and Dobson: Melbourne.

Provides a guide to establishing and managing agroforestry systems including discussions on selecting agroforestry combinations and tree species, establishing agroforestry and its management, and economics of the practice. Examples are given of agroforestry practices in both Australia and New Zealand. Australian and international research is discussed and used to identify future directions (in 1986).

Riemer, N. (ed). (1986). Trees: Why We Need Them. Australian Broadcasting Corporation: Sydney.

Developed as a means of sharing some of the experiences of entrants in the 1985 National Tree Care Award. Outlines uses of trees on farms and provides a step by step guide to preparing a plan for a rural property. Includes guidelines for layout and design of plantings for particular purposes, species selection and monitoring, and examples of farm tree plans.

Roach, G.L. and Kirkpatrick, R.D. (undated). Wildlife use of roadside woody plantings in Indiana. *Transportation Research Record* **1016**: 11-15.

A program of right-of-way (ROW) plantings for wildlife along highways was implemented in 1976 by the Indiana Department of Natural Resources, USA, in response to concerns that removal of fencerows was reducing wildlife habitat. This study was established to investigate the use of these plantings by birds and mammals in comparison with grassed plots. Planted ROWs attract a greater number and diversity of wildlife, particularly birds. Nesting was observed in plantings. Roadkills did not increase in areas with plantings. Roadsides and fencerows in Indiana and Ohio contribute considerably to the total area of habitat available to wildlife.

Roberts, B. (1992). Land Care Manual. New South Wales University Press: Kensington, NSW.

Discusses the issue of land degradation in Australia. It concentrates on agriculture and pastoral land and focuses on corrective measures that land holders and responsible authorities could undertake. Land care methods discussed include those primarily for soil stabilisation and improvement, although sustainable farming practices, clearing and planting trees, minesite rehabilitation, and wildlife management for the retention and control of native species are also covered.

Robins, L., McIntyre, K. and Woodhill, J. (1996). Farm Forestry in Australia: Integrating Commercial and Conservation Benefits. Greening Australia Ltd.: Canberra.

This report provides general background on farm forestry and presents Greening Australia's perspective. Includes sections which define farm forestry, identify the major stakeholders, discuss the role of farm forestry in ecological sustainability, outline the development of farm forestry, identifies state initiatives and opportunities for farm forestry, and discusses the commercial realities of, and impediments to, farm forestry.

Robinson, D. and Traill, B.J. (1996). Conserving woodland birds in the wheat and sheep belts of southern Australia. *Wingspan* (Supplement) **6**: 1-16.

An important statement that documents and discusses the clearing of temperate woodlands in Australia, land use practices and the implications for woodland wildlife (especially birds) and the rural landscape. Discusses disturbance processes and threats to the conservation of the woodland avifauna, and outlines priorities for conservation and management of the woodland ecosystem in southern Australia.

Rural Industries Research and Development Corporation (1999). RIRDC Home Page. Available URL: http//:www.rirdc.gov.au

Ryan, P.A. (1993). The utilisation of natural and planted linear habitats by birds in northern Victoria. B.Sc. (Hons) Thesis. Deakin University, Melbourne.

A study of the relative occurrence of bird species in linear strips of planted habitat (shelterbelts) and remnant natural vegetation (roadside vegetation) in the Goulburn Broken Catchment, Victoria. Compares the richness and composition of the avifauna in transects in each habitat type and highlights differences.

Ryan, P.A. (in press). The use of revegetated areas by vertebrate fauna in Australia: a review. Chapter 19 *in* Temperate Eucalypt Woodlands in Australia: Biology, Conservation, Management and Restoration. (Eds. R.J. Hobbs and C.J. Yates). Surrey Beatty and Sons: Chipping Norton, New South Wales.

Reviews published information on the occurrence of birds, mammals, reptiles and amphibians in revegetated habitats in Australia. Highlights the lack of comprehensive studies and paucity of knowledge for all groups, and the need to obtain comprehensive information to guide current and future revegetation strategies.

Sarré, S., Smith, G.T. and Myers, J.A. (1995). Persistence of two species of gecko (*Oedura reticulata* and *Gehyra variegata*) in remnant habitat. *Biological Conservation* **71**: 25-33.

Compared the occurrence of two species of gecko, a habitat specialist and a habitat generalist, in remnant woodland patches in Western Australia. Persistence of the habitat specialist in remnants is primarily related to the amount of suitable habitat, rather than the capacity for interchange between remnants, because this species has little likelihood of crossing open farmland. The habitat generalist has a greater ability to disperse, and hence to form a metapopulation consisting of a set of interacting populations.

Saunders, D.A. (1989). Changes in the avifauna of a region, district and remnant as a result of fragmentation of native vegetation: the wheatbelt of Western Australia – a case study. *Biological Conservation* **50**: 99-135.

Examined the avifauna of the wheatbelt at three spatial scales – region, district and individual remnant (patch). Changes over the 80-90 years prior to the study are described. Of 148 species of land birds recorded in the region, two had gone extinct. At the district level, more species had gone extinct although numbers varied according to extent of native vegetation removal and time since clearing. An example of an 81 ha remnant is provided, from which three species had gone extinct over the 10 years prior to the study. It is recommended that remnant vegetation needs to be retained, areas which include species that have declined should be identified and included in a network of reserves, priorities for management should be developed, and local communities involved in management of local conservation systems.

Saunders, D.A. (1993). A community-based observer scheme to assess avian responses to habitat reduction and fragmentation in south-western Australia. *Biological Conservation* **64**: 203-218.

Describes a community-based atlas scheme to determine the present distribution and abundance of birds in the Western Australian wheatbelt region. Compares the results of this scheme with historical records to establish the effects of changing land use on native birds. Recorded 109 species of non-passerines, of which 34 had decreased in range or abundance and nine had increased. Changing land use had a greater effect on passerines with 62 species (75%) decreasing in range and/or abundance and no species increasing, compared with non-passerines.

Saunders, D.A. (1994). Can we integrate nature conservation with agricultural production? *Landscape and Urban Planning* **28**: 63-71.

Discusses an approach being developed in south-western Australia to integrate nature conservation and soil conservation into farm management at the landscape district level.

Saunders, D.A. (1996). Does our lack of vision threaten the viability of the reconstruction of disturbed ecosystems? *Pacific Conservation Biology* **2**: 321-326.

Reviews the history of awareness and response to the influence of agricultural development on land degradation, loss of species and potential decreases in productivity. While there is considered to be an abundance of analysis and reporting of the problems and a range of responses, there appears to be a lack of long-term planning. Concludes that there is a need to develop a collective vision for future landscapes to provide a framework for integrating nature conservation with management for agricultural production and addressing environmental problems.

Saunders, D.A. and Curry, P.J. (1990). The impact of agricultural and pastoral industries on birds in the southern half of Western Australia: past, present and future. *Proceedings of the Ecological Society of Australia* **16**: 303-321.

Discusses the impact of European development on the avifauna of the Kellerberrin district and Murchison River catchment in the central wheatbelt of Western Australia. Outlines marked changes in the avifauna of the central wheatbelt over the previous 80 years with many species declining in number and some invading from adjacent pastoral districts. Possible scenarios for future changes in these environments and their management are discussed.

Saunders, D. A. and de Rebeira, P. (1991). Values of corridors to avian populations in a fragmented landscape. Pp 221-240 *in* Nature Conservation 2: The Role of Corridors. (Eds. D. A. Saunders and R. J. Hobbs). Surrey Beatty and Sons: Chipping Norton, New South Wales.

Describes results from banding studies of birds at a number of sites in roadside vegetation, patches of remnant vegetation and conservation reserves within a 624 km^2 area. Numbers of birds banded and recaptured are listed for all species, and diagrams summarising movements for some species are presented. The significance of bird movements is discussed in relation to the persistence of species in the fragmented landscape and the status of the regional avifauna.

Saunders, D. and Hobbs, R. (eds.) (1991). Nature Conservation 2: The Role of Corridors. Surrey Beatty and Sons: Chipping Norton, New South Wales.

Presents proceedings of a workshop held in 1989 at Busselton, Western Australia, to address biological concerns and practical management of corridors. Papers presented addressed a range of topics including inventory and assessment of corridors, values of corridors, movement of biota, and management (establishment, maintenance, rehabilitation) issues.
Other books in the series are:

Saunders, D., Arnold, G., Burbidge, A. and Hopkins, A. (eds.) (1987). Nature Conservation: The Role of Remnants of Native Vegetation. Surrey Beatty and Sons: Chipping Norton, New South Wales.

Saunders, D., Hobbs, R. and Ehrlich, P. (eds.) (1993). Nature Conservation 3: Reconstruction of Fragmented Ecosystems – Global and Regional Perspectives. Surrey Beatty and Sons: Chipping Norton, New South Wales.

Saunders, D.A., Craig, J.L. and Mattiske, E.M. (eds.) (1996). Nature Conservation 4: The Role of Networks. Surrey Beatty and Sons: Chipping Norton, New South Wales.

Saunders, D.A., and Hobbs, R.J. (1995). Habitat reconstruction: the revegetation imperative. Pp 104-112 *in* Conserving Biodiversity: Threats and Solutions. (Eds. R.A. Bradstock, T.D. Auld, D.A. Keith, R.T. Kingsford, D. Lunney and D.P. Siverston). Surrey Beatty and Sons: Chipping Norton, New South Wales.

Discusses the urgent need to reconstruct habitats using revegetation as the primary tool. Highlights the need for revegetation to recreate ecological systems rather than merely re-establish vegetation. Reconstruction needs to be approached at a scale which has ecological relevance (e.g. catchment scale) rather than at the individual farm level. The need for such measures is explained with a review of the current state of land degradation and extinction in Australia, with particular emphasis on the wheat-sheep zone, and a discussion of what needs to be done to control or reverse the current decline. Suggests guidelines for achieving habitat reconstruction and other land protection benefits.

Saunders, D., Arnold, G., Burbidge, A. and Hopkins, A. (eds.) (1987). Nature Conservation: The Role of Remnants of Native Vegetation. Surrey Beatty and Sons: Chipping Norton, New South Wales.

Presents papers from a conference/workshop held in 1985 at Busselton, Western Australia, to address problems associated with management of isolated remnants.
Other books in the series are:

Saunders, D. and Hobbs, R. (eds.) (1991). Nature Conservation 2: The Role of Corridors. Surrey Beatty and Sons: Chipping Norton, New South Wales.

Saunders, D., Hobbs, R. and Ehrlich, P. (eds.) (1993). Nature Conservation 3: Reconstruction of Fragmented Ecosystems – Global and Regional Perspectives. Surrey Beatty and Sons: Chipping Norton, New South Wales.

Saunders, D.A., Craig, J.L. and Mattiske, E.M. (eds.) (1996). Nature Conservation 4: The Role of Networks. Surrey Beatty and Sons: Chipping Norton, New South Wales.

Saunders, D.A., Craig, J.L. and Mattiske, E.M. (eds.) (1996). Nature Conservation 4: The Role of Networks. Surrey Beatty and Sons: Chipping Norton, New South Wales.

Presents proceedings of a workshop held in 1992 at Geraldton, Western Australia, to address the importance of people in achieving conservation and how networks of people can be formed, maintained and involved in nature conservation. Papers presented address a range of topics including the development and maintenance of networks, biological networks, and networks of indigenous people, landcare groups and property owners, mining and environmental consultants, communities, agencies and community, and conservation education and extension networks.
Other books in the series are:

Saunders, D., Arnold, G., Burbidge, A. and Hopkins, A. (eds.) (1987). Nature Conservation: The Role of Remnants of Native Vegetation. Surrey Beatty and Sons: Chipping Norton, New South Wales.

Saunders, D. and Hobbs, R. (eds.) (1991). Nature Conservation 2: The Role of Corridors. Surrey Beatty and Sons: Chipping Norton, New South Wales.

Saunders, D., Hobbs, R. and Ehrlich, P. (eds.) (1993). Nature Conservation 3: Reconstruction of Fragmented Ecosystems – Global and Regional Perspectives. Surrey Beatty and Sons: Chipping Norton, New South Wales.

Saunders, D.A., Hobbs, R.J. and Arnold, G.W. (1993). The Kellerberrin project on fragmented landscapes: a review of current information. *Biological Conservation* **64**: 185-192.

Reviews information from a major CSIRO study of the effects of fragmentation, the conservation potential of remnants of native vegetation, and options available for their management. The study examines the structure and dynamics of individual remnants and remnant networks within an agricultural matrix in a 1680 km^2 area of the central wheatbelt of Western Australia. This paper summarises information on remnant vegetation in the Kellerberrin area and the effects of fragmentation on vegetation and fauna, as a background for other papers in this issue of Biological Conservation.

Saunders, D., Hobbs, R. and Ehrlich, P. (eds.) (1993). Nature Conservation 3: Reconstruction of Fragmented Ecosystems – Global and Regional Perspectives. Surrey Beatty and Sons: Chipping Norton, New South Wales.

Presents the proceedings of a workshop held in October 1991 at Tammin, in the central wheatbelt of Western Australia, to address the issue of reconstructing fragmented ecosystems. Papers presented addressed a range of topics including global, regional and local perspectives of restoration, and how to make restoration ecology work.
Other books in the series are:

Saunders, D., Arnold, G., Burbidge, A. and Hopkins, A. (eds.) (1987). Nature Conservation: The Role of Remnants of Native Vegetation. Surrey Beatty and Sons: Chipping Norton, New South Wales.

Saunders, D. and Hobbs, R. (eds.) (1991). Nature Conservation 2: The Role of Corridors. Surrey Beatty and Sons: Chipping Norton, New South Wales.

Saunders, D.A., Craig, J.L. and Mattiske, E.M. (eds.) (1996). Nature Conservation 4: The Role of Networks. Surrey Beatty and Sons: Chipping Norton, New South Wales.

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

A timely and important review of current knowledge of the physical effects of landscape fragmentation, the biological consequences of these effects, and priorities for conservation research and management. Emphasizes the importance of land uses and processes in the matrix surrounding remnants, and argues that these will have a greater influence on conservation than the dynamics within remnants.

Schaefer, P.R., Dronen, S. and Erickson, D. (1987). Windbreaks: a plains legacy in decline. *Journal of Soil and Water Conservation* **July-August**: 237-238.

Documents the results of a survey assessing the declining condition of windbreaks on the Great Plains, Sth Dakota, USA.

Schofield, N.J. (1991). Tree planting for dryland salinity control in Australia. Pp Salinity 1-19 *in* The Role of Trees in Sustainable Agriculture: A National Conference. Proceedings. (Ed. R. Prinsley). Bureau of Rural Resources, Department of Primary Industries and Energy: Canberra.

Outlines (1) the extent of secondary salinisation in Australia; (2) technical aspects of the salinity problem including understanding its cause, the factors affecting its manifestation and determining what vegetation mixes can physically control the problem; (3) economic and financial aspects; (4) socio-political factors; (5) administrative and management approaches; and (6) future needs and progress.

Schofield, N.J., Bari, M.A., Bell, D.T., Boddington, W.J., George, R.J. and Pettit, N.E. (1991). The role of trees in land and stream salinity control in Western Australia. Pp. Salinity 21-43 *in* The Role of Trees in Sustainable Agriculture: A National Conference. Proceedings. (Ed. R. Prinsley). Bureau of Rural Resources, Department of Primary Industries and Energy: Canberra.

Presents experimental evidence which shows that replanting trees on farmland can halt and reverse rising groundwater. A range of planting strategies are investigated and it is concluded that the most promising strategy is dense replanting in valleys or adjacent sideslopes.

Schroeder, R.L. (1986). Habitat Suitability Index Models: Wildlife Species Richness in Shelterbelts. U.S. Fish and Wildlife Service Biological Report 80 (10.128).

Provides a synthesis of information available in 1986 on factors influencing wildlife use of shelterbelts in the USA, and outlines a habitat suitability index model based on this information. Literature is reviewed from the Great Plains states of South Dakota, North Dakota, and Minnesota. Data from these studies indicate that wildlife species richness is influenced by area, number of rows, structure and composition of shelterbelts. With increasing age, and therefore size and complexity, of shelterbelts, wildlife species diversity increases. Spatial and management considerations for shelterbelts are also considered. These factors are then applied to a habitat suitability index model for predicting wildlife species richness in shelterbelts and windbreaks in the northern Great Plains states.

Schroeder, R.L., Cable, T.T. and Haire, S.L. (1992). Wildlife species richness in shelterbelts: test of a habitat model. *Wildlife Society Bulletin* **20**(3): 264-273.

Presents results of a three year study of birds in shelterbelts of south-central Kansas in the Great Plains, USA, conducted to test the hypothesis presented in the original habitat model (Schroeder 1986) that species richness can be predicted by shelterbelt characteristics. A total of 62 bird species were observed in the 34 shelterbelts during 1988-1990. Bird species richness (BSR) was highly correlated with shelterbelt area. Shelterbelt isolation and distance to nearest farmstead had no relationship to BSR. Species richness was associated with vegetation structure, and the richness of cavity nesters (15 species comprising 24% of overall BSR) was highly correlated with snag density. Modifications of the original habitat suitability index (HIS) model to improve its predictive capabilities are recommended.

Schroeder, W. R. and J. Kort (1989). Shelterbelts in the Soviet Union. *Journal of Soil and Water Conservation* **44**: 130-134.

This article stems from a 1987 Canadian study tour of the former Soviet Union to discuss shelterbelts with Soviet scientists and observe plantings first-hand. The history of shelterbelt establishment in the former Soviet Union is outlined where, since the middle of the 19^{th} Century, more than 2.5 million ha of shelterbelts have been established to protect 19.8 million ha of agricultural land. Discusses recent (1987) programs and research, benefits of shelterbelts, and includes recommendations for tree planting techniques, including species and design.

Scougall, S. A., Majer, J.D. and Hobbs, R.J. (1993). Edge effects in grazed and ungrazed Western Australian wheatbelt remnants in relation to ecosystem reconstruction. Pp 163-178 *in* Nature Conservation 3: The Reconstruction of Fragmented Ecosystems. (Eds. D. A. Saunders, R. J. Hobbs and P. R. Ehrlich). Surrey Beatty & Sons: Chipping Norton, New South Wales.

Shalaway, S.D. (1985). Fencerow management of nesting birds in Michigan. *Wildlife Society Bulletin* **13**: 302-306.

Surveyed 4.6 km of fencerows on farmland in Ingham County, Michigan, USA, for nesting birds. Found 152 nests of 16 species – an average of 43.5 nests/ha. Nest densities were higher in fencerows than in natural shrub habitats. Increasing nest density was associated with fencerow width; wider fencerows were older and typically more heterogeneous. The density and diversity of nests increased with shrub abundance and was also influenced by adjacent field type. Nest success was attributed to the absence of avian nest predators rather than fencerow structure. Recommendations are made for management to encourage selected groups of birds to nest in fencerows.

Simberloff, D. and Tebo, M. (1994). Corridors for conservation: do habitat-connecting corridors really help birds? *Living Bird* **Winter**: 9-14.

Argues that there is a lack of scientific evidence to prove that species travel through wildlife ‘movement corridors’ instead of the surrounding habitat. Examples from the USA are used to illustrate problems with funding priorities where large sums of money were allocated for corridors with no evidence that they would be useful. Concern is expressed that the value of movement corridors may be confused with that of natural linear habitats (e.g. riparian habitat) which deserve protection for the species adapted to them. Acknowledges that it would be prudent to establish corridors now and that even small contributions to conservation may be significant, but emphasises the costliness of corridors means other options may not be pursued. An alternative approach is outlined whereby an entire landscape is managed to enable human activities to be compatible with conservation of entire biotic communities.

Simpfendorfer, K.J. (1989). Trees, Farms and Fires. Lands and Forests Bulletin No. 30. Department of Conservation, Forests and Lands: Melbourne.

Brings together information concerning the way in which rural lands can be protected from fire with a well designed and maintained system of shelterbelts. Includes discussion of how trees are affected by fire (including likelihood of regeneration after a fire), species selection for fire shelterbelts, economics of shelterbelts, fuel reduction burning and protecting trees from fire.

Simpson, K. and Day, N. (1996). A Field Guide to the Birds of Australia. 5th Edition. Penguin Books Australia Ltd.: Melbourne.

Provides a comprehensive guide to Australia's avifauna. Includes: a key to families; field information, colour plates, descriptions, and distribution maps for each species; and a 'handbook' section which describes the life cycle of birds, where birds live (vegetation and landform habitats of Australia) and avifaunal regions, provides hints for bird-watchers, and describes each of the bird families in Australia.

Sly, G. (1976). Small mammal succession on strip-mined land in Vigo County, Indiana. *The American Midland Naturalist* **95**: 257-267.

Studied the small mammals of three strip-mined areas abandoned at various times to determine the relationship between vegetative and small-mammal succession. Seven species of small mammal were recorded although three were only recorded in one area. Herbaceous cover was not a major limiting factor for either species. The results of this study are compared with another conducted in 1957.

Smith, G.T., Arnold, G.W., Sarre, S., Abensperg-Traun, M. and Steven, D. (1996). The effect of habitat fragmentation and livestock grazing on animal communities in remnants of gimlet *Eucalyptus salubris* woodland in the Western Australian wheatbelt. II Lizards. *Journal of Applied Ecology* **33**: 1302-1310.

Studied the occurrence of lizard species in remnants of gimlet woodland in the Western Australian wheatbelt, and examined the relationships between occurrence, species richness and abundance of lizard taxa and measured habitat and biogeographic attributes of remnants. Habitat variables representing cover, shelter and foraging substrates were important correlates of the use of woodland remnants by lizards.

Sorenson, C.J. and Marotz, G.A. (1977). Changes in shelterbelt mileage statistics over four decades in Kansas. *Journal of Soil and Water Conservation* **November-December**: 276-?

Outlines over 100 years of tree planting programs in the Great Plains. Presents results of a 13-county survey conducted in Kansas which suggest that about 20% of the state's shelterbelt mileage had been removed since the late 1950s. Reasons for decline are discussed.

Sotherton, N.W., Wratten, S.D., Price, S.B. and White, R.J. (1981). Aspects of hedge management and their effects on hedgerow fauna. *Zeitschrift Fuer Angewandte Entomologie* **92**: 425-432.

Sampled the arthropod fauna of nine hedgerows in Hampshire, UK and also used supporting data from hedges in Northumberland, U.K. Hedges were divided into three management categories – cut, uncut and remnant – of which cut hedges were found to have the highest faunal diversity. Management implications for arthropod fauna are discussed.

Sparks, T.H. and Parish, T. (1995). Factors affecting the abundance of butterflies in field boundaries in Swavesey Fens, Cambridgeshire, UK. *Biological Conservation* **73**: 221-227.

Surveyed butterfly populations of Cambridgeshire field boundaries in 1986 and 1991. Related characteristics of field boundaries and field boundary flora to abundance of individual butterfly species, total abundance and species richness. Found butterfly populations were enhanced in field boundaries containing large hedgerows, high plant species richness and grassy areas in the form of verges or ditch banks; features more usually associated with edges of pasture fields. Additional data are included which suggest the detrimental effect of agrochemical applications to butterflies. Also discusses the importance of field boundaries in providing a network for movement between habitat patches.

Sparks, T.H., Parish, T. and Hinsley, S.A. (1996). Breeding birds in field boundaries in an agricultural landscape. *Agriculture, Ecosystems and Environment* **60**: 1-8.

Censused the breeding bird populations of 117 field boundary transects in an agricultural, non-wooded landscape in Cambridgeshire, UK, over three years. Examined bird distribution and persistence in relation to attributes of the field boundaries and adjacent land use. Found substantial differences in hedge height preferences, with the distribution of bird species appearing to be dominated by factors related to nest site selection. Woodland species were found primarily in tall hedgerows (often the only woody vegetation available in the landscape), while open-country species preferred grassy or scrub-like boundaries. Surrounding land use was also significant for certain species. Management of hedgerows and other field boundaries to encourage the presence of breeding birds is discussed.

State of the Environment Advisory Council (1996). Australia: State of the Environment 1996. CSIRO Publishing: Melbourne.

Documents the State of the Environment Advisory Council's findings on the state of the Australian environment including the human settlements, biodiversity, the atmosphere, land resources, inland waters, estuaries and the sea, natural and cultural heritage. An assessment of the findings of the state of the environment report and of Australia's progress towards ecologically sustainable development is also included. It is concluded that, despite positive achievements to date, some serious adverse trends need urgent attention.

Stauffer, D.F. and Best, L.B. (1980). Habitat selection by birds of riparian communities: evaluating effects of habitat alterations. *Journal of Wildlife Management* **44**(1): 1-15.

Studied habitat selection and relative tolerance of habitat alterations of the avifauna of riparian communities in Guthrie County, Iowa, USA. Life form, microhabitat, plant species richness, and presence of cavities were considered as influences on habitat selection. Generally, wooded habitat supported more species and higher densities than herbaceous habitats and bird species richness increased with width of wooded riparian habitats. Specialisation of species was considered and evaluated in terms of tolerance to habitat alterations.

Stelling, F. (1994). Revegetation Guide for North-eastern Victoria. Department of Conservation and Natural Resources: Melbourne.

Provides general information on: the values of remnant vegetation and the need for fencing to protect it; environmental weeds; the role of native grasses for revegetation, wildlife and agriculture; planting and direct seeding to establish vegetation; streamsides and farm dams; shelterbelts; agroforestry; native plant seed collection and storage; native plant propagation from cuttings or seed; and mistletoe ecology and management. Includes a vegetation profile for subcatchments with a list of appropriate species including trees, shrubs, climbers and understorey species. Descriptions of species include their habit, distribution, site preference (soils and rainfall) and include characteristics of flowering patterns, seed collection time, propagation, effectiveness of establishment methods, values for timber, fuel, land protection, agroforestry, shade and shelter, wildlife, honey production, and ornamental value.

Other revegetation guides for Victoria by the same author, year and publisher are:

- Revegetation Guide for the Upper Murray: Lower Section.
- Revegetation Guide for the Upper Murray: Upper Subcatchments.
- Revegetation Guide for the Black Dog Basin and Neighbouring Areas.
- Revegetation Guide for the Kiewa Basin.
- Revegetation Guide for the Ovens Basin: Upper Subcatchments.
- Revegetation Guide for the Ovens Basin: Mid and Lower Sections.

Strahan, R. (1995). The Mammals of Australia. Reed Books: Sydney.

Provides an account of every species known to have existed in Australia since European settlement and every introduced species. The habitat, distribution, behaviour, diet, breeding and threats of each species are described. Colour photographs of each species are included.

Swihart, R. K. and R. H. Yahner (1982). Habitat features influencing use of farmstead shelterbelts by the eastern cottontail (*Sylvilagus floridanus*). *American Midland Naturalist* **107**(2): 411-414.

Examines the use of five farmstead shelterbelts by rabbits in south-eastern Minnesota, USA. Trap use in summer and autumn was primarily determined by proximity and density of shrubby vegetation, although coniferous overstorey vegetation and mowed grassy areas were also associated with use during these seasons.

Taylor, R. (1994). Trees for profit and land care. *Rural Research* **163**: 31-35.

Discusses the value of farm plantations to address land care issues, such as salinity and rising water tables, and as a potential cash crop. Research being conducted into suitable tree species for such purposes is outlined including some results of the Trees for Profit program and the South Australian Department of Primary Industries' farm-tree improvement program. The extent of tree establishment required to improve sustainability on farms has been investigated by Department of Agriculture, Victoria, who suggest up to 20% of the total farm area. Market trends and values of trees for pulp or timber is outlined and the need for co-operatives is explained.

Thomas, M.B., Sotherton, N.W., Coombes, D.S. and Wratten, S.D. (1992). Habitat factors influencing the distribution of polyphagous predatory insects between field boundaries. *Annals of Applied Biology* **120**(2): 197-202.

Investigated the winter distributions of polyphagous predators in relation to field boundary structure in Hampshire, UK. Six predator species were recorded. The distribution of one species was positively correlated with the density of Cocksfoot *Dactylis glomerata* tussocks while percentage cover of deciduous leaf litter was positively correlated with two other species. No further relationships explained the observed predator distribution patterns.

Thorburn, P. (1996). Can shallow water tables be controlled by the revegetation of saline lands? *Australian Journal of Soil and Water Conservation* **9**: 45-50.

Reviews the results of studies investigating the uptake of groundwater by plants and compares them with discharge rates from bare soils. Factors limiting groundwater uptake by plants are discussed and models to estimate uptake are also examined to determine conditions most likely to increase groundwater discharge by plants. Finally, the long-term viability of vegetation in saline lands is discussed.

Tisdell, C.A. (1985). Conserving and planting trees on farms: lessons from Australian cases. *Review of Marketing and Agricultural Economics* **53**(3): 185-194.

Discusses the economics (up until 1985) of conserving and planting trees on farms using case studies of shelterbelts on four Victorian farms, agroforestry using radiata pine in the southern tablelands of NSW, eucalypt dieback in New England area, and dryland salting. Illustrates the diversity of issues to be considered when determining economic costs and benefits of tree conservation, maintenance and planting on farms for both private landholders and the wider community. The case studies are used to illustrate such complexity, however other areas such as the higher rainfall zone will have different requirements and need to be studied further.

Triggs, B. (1996). Tracks, Scats and Traces: A Field Guide to Australian Mammals. Oxford University Press.

A guide to assist with identification of mammalian traces. This book is divided into four sections: (1) tracks; (2) scats; (3) shelters, feeding signs and other traces; and (4) bones. Characteristic traces of individual species or groups of species are outlined in each section. Diagrams and photographs of mammalian traces, and species distribution maps assist with identification.

Usher, M.B, Field, J.P. and Bedford, S.E. (1993). Biogeography and diversity of ground-dwelling arthropods in farm woodlands. *Biodiversity Letters* **1**: 54-62.

Sampled the ground beetle and spider fauna of 28 farm woods (planted since the beginning of the century) in the Vale of York, England. A total of 47 species of ground beetle (4422 individuals) and 97 species of spider (3476 individuals) were recorded. Species richness in individual woodlands ranged from 10-22 species for ground beetles and 15-34 species for spiders. Ground beetle species richness was related to woodland shape and area; woodlands with high edge to area ratios and larger in area supported more species. Spider richness was related to isolation; less isolated woodlands supported more species. These results indicate features which could be incorporated into new areas of farm woodland to increase their conservation value for invertebrates.

van der Moezel, P.G. and Bell, D.T. (1990). Saltland reclamation: selection of superior Australian tree genotypes for discharge sites. *Proceedings of the Ecological Society of Australia* **16**: 545-549.

Presents a summary of a three-year research programme which began in 1986 to select woody species tolerant of saline and waterlogging conditions. Eight screening trials were conducted on 101 species of *Acacia, Casuarina, Eucalyptus* and *Melaleuca*. This summary highlights species performances, intraspecific variation, and physiological data, and guidelines for future research in selecting trees for saltland reclamation are discussed.

van der Moezel, P.G., Pearce-Pinto, G.V.N. and Bell, D.T. (1991). Screening for salt and waterlogging tolerance in *Eucalyptus* and *Melaleuca* species. *Forest Ecology and Management* **40**: 27-37.

van Schagen, J. J., Hobbs, R. J. and Majer, J. D. (1992). Defoliation of trees in roadside corridors and remnant vegetation in the Western Australian wheatbelt. *Journal of the Royal Society of Western Australia* **75**: 75-81.

The abundance and impact on trees of bag-shelter caterpillars were compared in roadside vegetation and in a large reserve in the Western Australian wheatbelt. The number of bags per tree was greater on narrow verges than on medium or wide verges. Caterpillars caused severe damage to roadside trees during an outbreak. However, within the reserve caterpillars were initially present but failed to develop and reach maturity. Suggests that ecological processes in narrow corridors are modified compared to those in large tracts, and that this has implications for management of corridors.

Venning, J. (1988). Growing Trees for Farms, Parks and Roadsides: A Revegetation Manual for Australia. Lothian Publishing Company: Melbourne.

Aims to promote the re-establishment of trees on farms by providing practical advice on revegetation methods. Three techniques are discussed – natural regeneration, direct seeding and planting. The benefits and costs of each technique are identified and chapters are devoted to discussing methods for their implementation. Species selection, seed collection, site preparation and after care of vegetation are discussed. Planning for revegetation projects is emphasised and case studies are used to illustrate the most appropriate method for different situations.

Verboom, B. and H. Huitema (1997). The importance of linear landscape elements for the Pipistrelle *Pipistrellus pipistrellus* and the Serotine Bat *Eptesicus serotinus*. *Landscape Ecology* **12**(2): 117-125.

Studied the relationship between two species of bat and linear landscape elements such as hedgerows, tree lines and tree lanes in an agricultural area in the Netherlands. Differences in behaviour between the two species are discussed, for example, the Pipistrelle was observed almost entirely close to landscape elements while Serotine Bats cross fields and meadows more frequently. Three possible functions of linear elements for bats – as orientation clues, foraging habitat or shelter from wind and/or predators – are discussed.

Vought, L., Pinay, G., Fuglsang, A. and Ruffinoni, C. (1995). Structure and function of buffer strips from a water quality perspective in agricultural landscapes. *Landscape and Urban Planning* **31**: 323-331.

Discusses the importance of north European riparian forests and wetlands, hedges and stone fences in a landscape perspective for the improvement of water quality.

Wegner, J.F. and Merriam, G. (1979). Movements by birds and small mammals between a wood and adjoining farmland habitats. *Journal of Applied Ecology* 16: 349-358.

Investigated the connections between a beech-maple wood, and adjacent fields and fencerows in Canada, indicated by movements of birds and small mammals. Three species of small mammal were captured – Eastern Chipmunks used woods and fencerows but were never caught in fields; Meadow Jumping Mice used fencerows and fields but rarely used woods; and White-footed Mice were caught predominantly in woods and fencerows. Birds seldom flew directly across fields between woods, rather, more species moved more frequently between the wood and fencerows than between any other habitats. Poorly developed fencerow vegetation restricted foraging by wood-nesters into fields. Concludes that fencerows form a habitat corridor which may relieve the isolating effect of farmland surrounding the wood.

Wildin, J.H. (1990). Trees for fodder. Pp 377-382 *in* Trees for Rural Australia. (Ed. K.W. Cremer). Inkata Press: Melbourne.

Discusses the value of browse and considers the many benefits of fodder trees when selecting species suitable for farm plantings. There is also general discussion on the use and management of fodder tree and a list of suitable trees for broadscale planting is provided.

Williams, J., Hook, R.A. and Gascoigne, H.L. (1998). Farming Action – Catchment Reaction: The Effect of Dryland Farming on the Natural Environment. CSIRO Publishing, Melbourne.

Published as part of the CSIRO Dryland Farming Systems for Catchment Care Program that aims to undertake research into problems relevant to Landcare and catchment management groups. Includes sections addressing: social and economic issues; indicators of catchment health suitable for use by individual farmers and catchment and Landcare groups; linkages between farming systems and catchment land and water quality; and modelling farm production and catchment process including information on understanding models, and models and computer programs used in Australia for assessing and maintaining catchment and regional biodiversity.

Williamson, D.R. (1998). Land degradation processes and water quality effects: waterlogging and salinisation. Pp 162-190 *in* Farming Action: Catchment Reaction – The Effect of Dryland Farming on the Natural Environment. (Eds. J. Williams, R.A. Hook and H.L. Gascoigne). CSIRO Publishing: Melbourne.

This chapter provides a detailed review of the land degradation processes and water quality effects of waterlogging and salinisation in Australia.

Wilson, S.M., Whitham, J.A.H., Bhati, U.N., Horvath, D. and Tran, Y.D. (1995). Trees on Farms - Survey of Trees on Australian Farms: 1993-94. ABARE Research Report 95.7: Canberra.

The 'Trees on Farms' survey was undertaken to fill the perceived information gap on the nature and extent of trees on farms, or farmers' perceptions of the costs and benefits of these plantings. To ensure comprehensive national coverage of Australia's broadacre and dairy industries in the three agricultural zones (pastoral, wheat-sheep and high rainfall) of Australia, about 2000 farms were surveyed in 1994. The results of the questionnaire are presented in this report. Data are included for trees planted until 30 June 1994 and more recent plantings between 1991 and 1994 in various combinations including individual states, agricultural zones, and Australia as a whole.

Woodfull, J., Finlayson, B. and McMahon, T. (eds) (1993). The Role of Buffer Strips in the Management of Waterway Pollution from Diffuse Urban and Rural Sources. Proceedings of a workshop held 9 Oct 1992 at the University of Melbourne. Land and Water Resources Research and Development Corporation and University of Melbourne, Centre for Environmental Applied Hydrology. LWRRDC Occasional Paper No 01/93.

Presents a series of review papers on the role of buffer strips in helping to control water pollution from diffuse rural and urban sources by filtering sediment, nutrients and other contaminants before they reach the waterway. Buffer strips, in the form of natural riparian vegetation or as narrow planted strips in agricultural properties, also perform a variety of other functions, including acting as wildlife corridors, helping to maintain bank and channel stability and maintaining natural environmental conditions for instream biota. The ecological role of buffer strips is discussed, as are mechanisms operating within riparian zones and management strategies being implemented.

Yahner, R.H. (1982a). Avian nest densities and nest-site selection in farmstead shelterbelts. *Wilson Bulletin* **94**(2): 156-175.

Examines the suitability of seven farmstead shelterbelts as nesting habitats for birds in Minnesota, USA. Nest densities were used as a measure of suitability with 617 nests from 17 bird species noted over two years. Nest densities overall were greater than reported for non-wooded habitats in the region. Densities increased with the number of rows and age of shelterbelts. Choice of nesting substrate was not random and was based primarily on structural characteristics. Concludes that shelterbelts are important nesting habitats for birds despite their small size, and are sufficiently heterogeneous to enable several nesting species to coexist at high densities.

Yahner, R.H. (1982b). Microhabitat use by small mammals in farmstead shelterbelts. *Journal of Mammalogy* **63**(3): 440-445.

Studied the use of microhabitats by five small mammal species in five farmstead shelterbelts of southern Minnesota, USA. Characteristics of shelterbelts influencing the abundance of each species were analysed. It was concluded that use of microhabitats is both a function of foraging and predator-avoidance behaviour, similar to that reported in studies of natural habitats.

Yahner, R.H. (1982c). Avian use of vertical strata and plantings in farmstead shelterbelts. *Journal of Wildlife Management* **46**(1): 50-60.

Examined the use of vertical strata and plantings of trees and shrubs by 28 bird species in seven farmstead shelterbelts in Dakota County, Minnesota, USA. The majority of bird species (61%) were most often sighted in the ground stratum. Bird species best adapted to shelterbelts appeared to be generalists in strata and planting use. Recommends inclusion of five preferred genera of trees and shrubs in new shelterbelts or renovating old shelterbelts to benefit birds in intensively farmed regions by increasing vertical complexity and enabling coexisting species to partition the limited space available.

Yahner, R.H. (1983a). Small mammals in farmstead shelterbelts: habitat correlates of seasonal abundance and community structure. *Journal of Wildlife Management* **47**(1): 74-84.

Investigated the abundance and community structure of common small mammals in five farmstead shelterbelts (ranging from 0.21-0.79 ha, 3-9 rows) in southern Minnesota, USA, 1978-1980. Eleven species were captured in shelterbelts. None were agricultural pests suggesting shelterbelts were not used as habitat for noxious species. The relative abundance of each species reflected their different habitat requirements. Species diversity was associated with area and perimeter of shelterbelts. Abundance of different species varied with isolation from other wooded habitat. Richness was generally greater in larger shelterbelts with complex vegetation cover. Management recommendations include ensuring vertical stratification of vegetation by minimising mowing and excluding livestock; considering vegetation complexity; retaining woody and man-made debris (e.g. sheds or other junk); and providing large habitat when possible.

Yahner, R.H. (1983b). Seasonal dynamics, habitat relationships, and management of avifauna in farmstead shelterbelts. *Journal of Wildlife Management* **47**(1): 85-104.

Investigated seasonal trends in population dynamics and community structure of avifauna in farmstead shelterbelts; examined the relationship between habitat features and avifauna using shelterbelt habitat; and developed management recommendations for establishing or renovating shelterbelts. During the two year study based on seven farmstead shelterbelts in southern Minnesota, USA, 87 species of birds were recorded using shelterbelts. Nearly half of these were regarded as being adapted to man-made environments. Species richness and diversity were higher in spring and summer than winter and autumn. The avifauna associated with shelterbelts was influenced by perimeter and length of shelterbelts more than area, and by distance to remnant habitats and types of surrounding landuse. Management recommendations included establishing eight row shelterbelts of more than 0.6 ha in area, and a diversity of plantings. Discontinuing mowing and cultivation, having no minimum tillage systems, positioning croplands rather than pastures near shelterbelts, retaining snags, growing food plots and providing artificial feeders at farmhouses are also suggested.

Yahner, R. H. (1983c). Population dynamics of small mammals in farmstead shelterbelts. *Journal of Mammalogy* **64**: 380-386.

Studied aspects of the population dynamics of five species of small mammal in five farmstead shelterbelts of southern Minnesota, USA. Total numbers of all species were greatest in summer and autumn; juvenile recruitment was attributed to species-specific peaks in seasonal abundance. Movement within and between shelterbelts varied between species and was most affected by the isolation and linearity of these man-made islands. Concludes that these wooded habitats are important to small mammals in a region characterised by intensively agricultural land use and that efforts should be made to preserve them.

Zborowski, P. and Storey, R. (1995). A Field Guide to Insects in Australia. Reed Books.

This practical field guide provides a means to identify an insect to the level of order. Part 1 provides background information on insect appearance, life cycles and classification. Part 2 has a chapter for each of the 26 orders found in Australia. Each chapter describes characteristics that define the order and introduces major families within the order. The guide is illustrated with line drawings and more than 240 colour photographs of insects in their natural habitat.