Managing Natural Biodiversity in the Western Australian Wheatbelt

A Conceptual Framework

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Department of Conservation and Land Management
Conserving the nature of WA

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Preface

As has commonly occurred elsewhere in the world, land acquisition for conservation in Western Australia long preceded effective management. Although there have been major advances in the operational management of conservation lands since the Department of Conservation and Land Management formed in 1985, no conceptual framework for management has evolved that integrates fundamental human values with management planning, action and priority setting. Although many parts of such a framework exist, both at State and national levels, a fully integrated package has not been produced.

This is unfortunate. An effective conceptual framework for biodiversity management offers a consistent context in which workers may develop and implement management strategies. Properly structured, such a framework will challenge and improve management ideas and practice. An effective framework will also help managers understand the value of their work to society, and help inform the State community both as to the personal importance of biodiversity and the complexity of its management.

This document begins to redress the lack of a conceptual framework by developing one for operational management in the Wheatbelt Region of Western Australia. The framework was specifically designed for managers, planners and researchers working in agricultural areas, and assumes some knowledge of the relevant management issues. Despite the comparatively narrow geographic focus of the document, the ideas it contains are widely applicable in conservation management.

Reading through the framework is a salutary reminder of the complexity and difficulties of natural resource management in general, and biodiversity conservation in particular. As Executive Director of a conservation agency, I am conscious that we must frankly acknowledge management issues and encourage open discussion of problems and their solution. To be successful land managers, our Department engages a wide range of knowledge, experience and ideas. No one group has a mortgage on solutions. Given the essential services and other values biodiversity assets bring to our lives, it is vital that we all work together to manage, conserve and recover our native plants and animals.

From this perspective, the frameworks we use to drive and evaluate management are also an important part of engaging a wide variety of individuals and organisations. While a variety of conceptual frameworks could be proposed, I consider that the ideas put forward by the authors in this document challenge our thinking and provide one vehicle for engaging the broader community in constructive discussion of biodiversity conservation matters. As the authors themselves acknowledge, the ideas in the document will evolve with new information, constructive debate and practical experience.

I encourage people to read this document and help develop its ideas to improve our State's management of biodiversity.

Keiran McNamara
Executive Director

November 2003

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Introduction

Background

Globally, clearing native vegetation to create agricultural land has led to many areas where fragments of natural habitat persist in landscapes dominated by agriculture. As a consequence of habitat loss, biodiversity[1] conservation has suffered, an issue that has long been recognised. The papers in Saunders *et al.* (1987), Hobbs and Saunders (1993) and Saunders *et al.* (1993) provide an excellent introduction to the difficulties of managing biodiversity in such environments.

The comparatively recent history of vegetation clearing in agricultural areas of southern Australia, coupled with high levels of natural biodiversity, particularly in the south-west, has led to significant regional interest in conservation issues. Typically, these areas lie in zones of Mediterranean climate with modest rainfall. While pastoral income derived from sheep and sometimes cattle is common, the chief source of economic return is from cereal crops, mainly wheat.

During 1997 and 1998, a case study (Wallace 1998a) for planning biodiversity conservation in agricultural environments was developed around the Dongolocking conservation reserves (Figure 1) in the Wheatbelt Region[2] of Western Australia. This was a collaborative project involving local landholders and several government agencies. Since 1998, the ideas stimulated by this project have been further developed and now form a conceptual framework that supports biodiversity conservation management by the Department of Conservation and Land Management in the Wheatbelt Region.

This document was written to describe and explain this conceptual framework. Given that conserving Western Australia's natural biodiversity is a key statutory role of the Department, the document also underpins the biodiversity conservation section of the Wheatbelt Regional Plan currently being written for all departmental activities in the Region.

The framework deals with biodiversity conservation without regard to land tenure because the Department's statutory responsibilities for biodiversity extend across the State, and are not restricted to conservation reserves and parks. Also, native plants and animals do not recognise tenure boundaries; therefore, a framework for biodiversity conservation must consider all land tenures. For example, many threatened species and threatened ecological communities are found on private property, particularly in agricultural areas where there has been extensive, generally selective, clearing of land.

Although primarily written to underpin the Department's work in the wheatbelt, a second aim of this document is to provide a starting point for individuals and groups who have similar biodiversity conservation goals to those of the Department. While there is a considerable and valuable literature on biodiversity conservation management, we have not found another document that provides a broad framework within which to develop operational management strategies and priorities.

Furthermore, although this framework has been developed for an environment where the remaining natural habitats are mostly highly fragmented, many of the ideas and processes are applicable to biodiversity conservation elsewhere. Thus, in a wider context, the document has also been written to stimulate thinking about biodiversity conservation, particularly with a view to encouraging the elaboration of conceptual frameworks that link operational management of biodiversity with a broader set of ideas – a philosophy of management.

The ideas developed in this document have changed substantially over the past five years and will continue to evolve driven by new knowledge, debate and experience. A key to the evolution of ideas presented here has been the constant interaction between the development of concepts and their practical application. Also, the interplay between different institutions and functional groups – particularly research, planning and operations – has been vital to the development of our ideas. In this regard it is hoped the document will stimulate further discussion and debate, and has been written in the expectation that the methods described will enjoy considerable improvement over the coming decade.

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[1] Unless otherwise stated, 'biodiversity' in this document always refers to natural biodiversity. Issues of definition are dealt with later in the document.

[2] The convention followed throughout this document is to use the term 'Wheatbelt Region' or 'Region' for the administrative region of the Department of Conservation and Land Management, and the term 'wheatbelt' where the broader sense is intended. That is, 'wheatbelt' refers to that part of the south-west where wheat is the most important cereal crop (Figure 1).

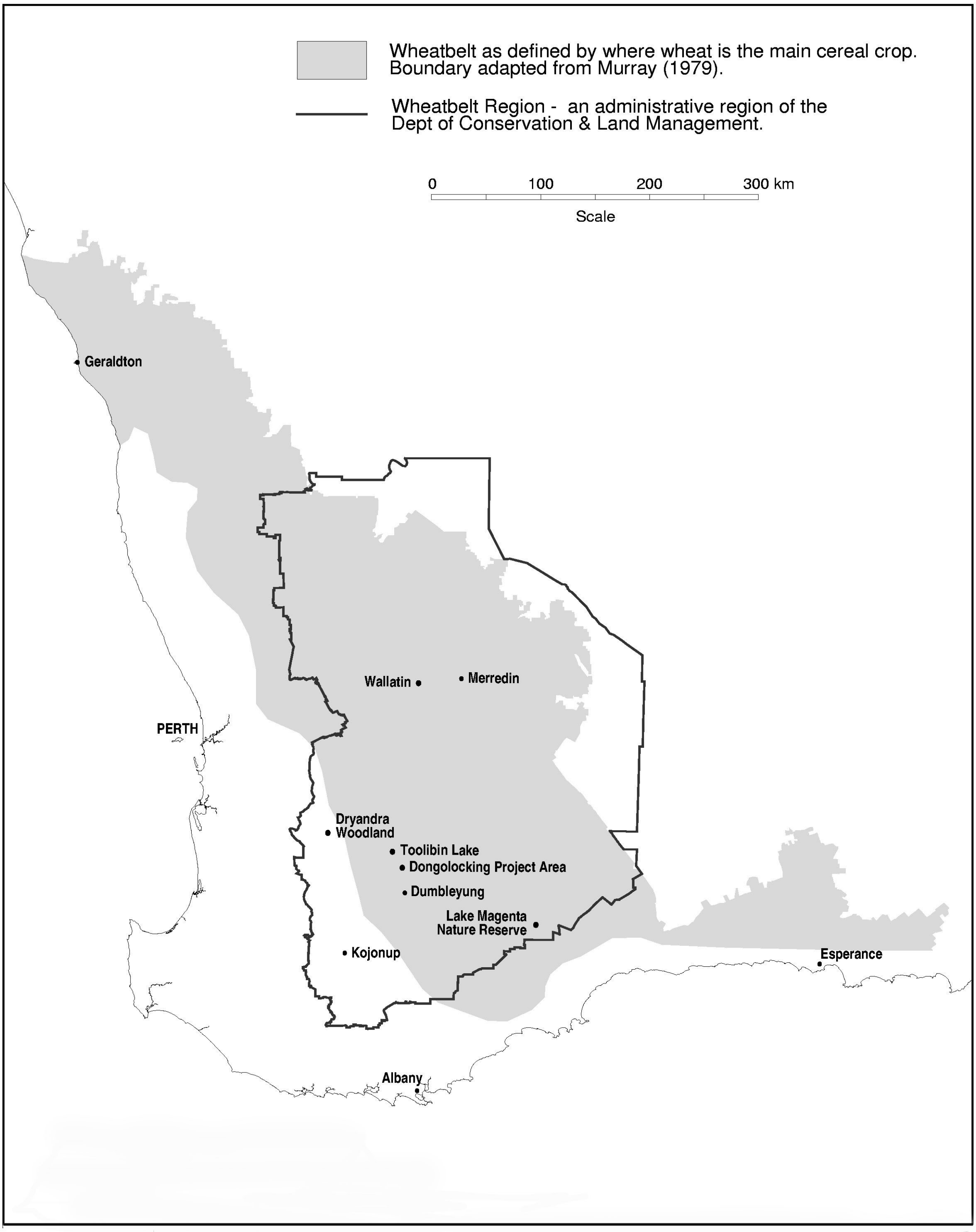


Figure 1: Wheatbelt boundaries and locations mentioned in the text.

Elements of a conceptual framework for biodiversity conservation

While working on the Dongolocking project, it was found essential to clarify the key environmental components of the wheatbelt including the related fluxes. An account of these is provided in Appendix 1 as a broad context for this framework.

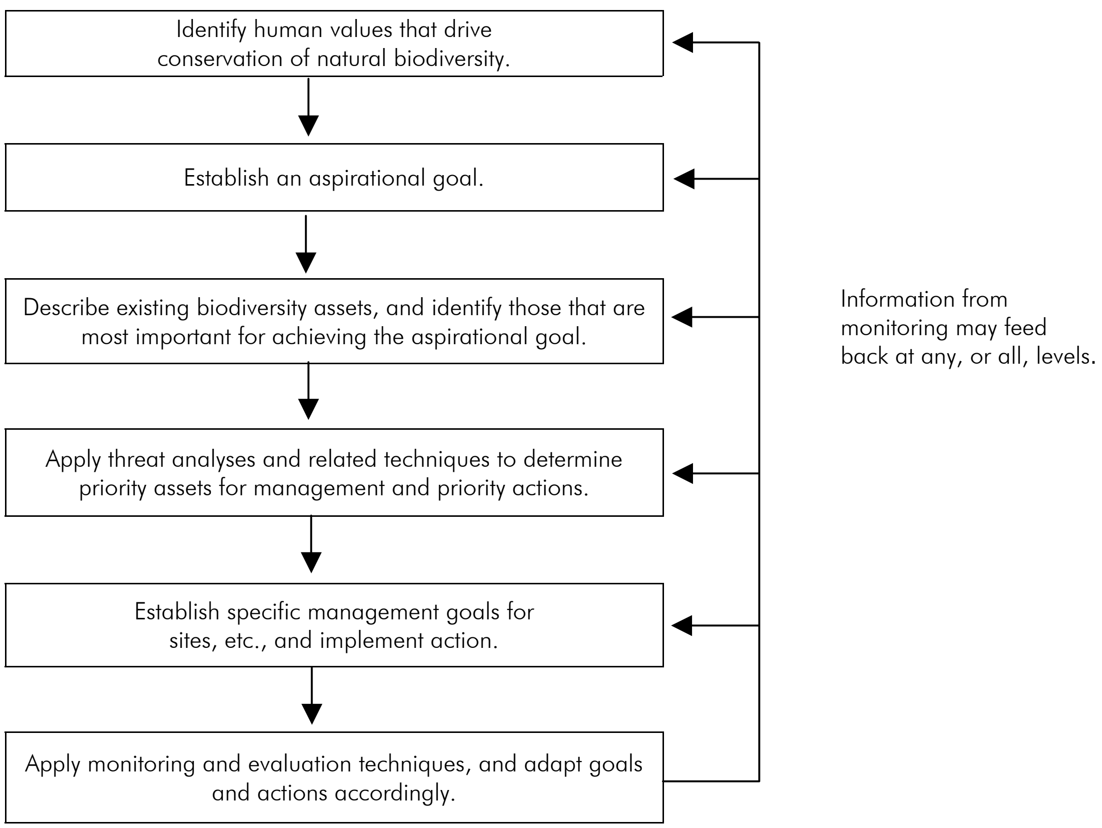
This framework for managing biodiversity includes four elements:

a. an aspirational goal and broad management strategies that guide operational management. In developing these, it is essential to recognise the human values driving them and to understand the appropriate spatial and temporal scales of management;
b. a description of the biodiversity assets that must be managed to achieve the aspirational goal;
c. a description of threats to goal achievement, and a process for using threats to rank management strategies and identify priority sites (or biodiversity assets) for action. Decisions from this process are implemented through management operations (not specifically considered in this document); and
d. monitoring and evaluation methods that effectively link goals, on-ground outputs and outcomes. These methods must provide the necessary feedback so that (a) to (c), including management actions, are adapted in the light of experience and new information.

The discussion below covers each of these elements. In a written document they are dealt with in a linear fashion but this is not an accurate description of the thought processes involved. In reality, many of these elements are developed simultaneously and there is a constant flow of information and ideas between all parts. For example, logically one develops goals before undertaking a threat analysis to goal achievement. However, goals are also shaped by the severity of particular threats and our knowledge of how to manage them. Thus the process is iterative and interactive, rather than linear.

Despite the iterative and interactive aspects of the process described in this framework, there is still a logical, sequential approach (Figure 2). Again using goals as the example, one cannot effectively begin planning operational management without some sense of direction. Thus goal formulation, no matter how broad or general it may be, must precede the development of management strategies. At the same time, it should be recognised that initial goals will usually change in the light of new information generated by later steps in the process, and goal formulation itself is understood better once the concepts of assets and threats are examined.

Figure 2: Flow diagram of key steps in managing for biodiversity conservation



Finally, as far as practicable, the level of explanation in the body of this document has been kept to a minimum to improve the flow and clarity of the text. To achieve this, appendices have been used to develop and explain some important issues that would otherwise require major diversions in the body of the document.

Values, vision and goals

Values and biodiversity conservation

Before setting goals for biodiversity conservation it is essential to understand which human values drive existing socio-political support for conservation. For many people, biodiversity conservation is an abstract idea disconnected from their lives and well-being. Therefore, it is important to describe the human values of biodiversity so that people understand its importance to them personally. Without such linkages, there would be little support for expending human resources – financial or otherwise – on conservation.

Consequently, for those managing biodiversity it is vital to ensure that management goals closely reflect human values and needs. If they do not, management work will be inconsistent with community expectations and is likely to be starved of resources.

In the wheatbelt, natural biodiversity contributes to the following human values:

a. consumptive use values;
b. productive use values;
c. opportunity values (such as the potential future use of genetic resources);
d. ecosystem service values;
e. amenity values;
f. scientific and educational values;
g. recreational values; and
h. spiritual/philosophical values.

These values and their connection to human quality of life are explained in Appendix 2. Biodiversity conservation, in the context of the relevant departmental goal (see next section), is thought of as primarily contributing to opportunity values, ecosystem service values, amenity values, scientific and educational values, and spiritual/philosophical values, together with passive recreation in natural environments (part of recreational values).

Given the significant opportunity values represented by the extraordinarily diverse native flora of the wheatbelt, the major ecosystem services provided by biodiversity and associated natural systems, and the contribution to mental and physical health delivered through recreation and spiritual values, the wheatbelt's biodiversity is very significant for individuals living both within and outside the region. There is also a strong case for asserting the interdependence of achieving sustainable, profitable land use and conservation of natural biodiversity. This is particularly so in agricultural areas such as the wheatbelt where the remaining natural environments are biodiverse and offer significant opportunity and ecosystem service values.

Corporate goal for biodiversity conservation – an aspirational goal

In the previous section the human values that underpin the corporate goal were listed. For a public institution in a democratic society, grounding the goal in human values links the institution to its socio-political environment. In this context, the Department's corporate goal (or objective) for conserving biodiversity is:

> *To protect, conserve and, where necessary and possible, restore Western Australia's natural biodiversity.*

To explain this goal fully three issues must be addressed – the definition of biodiversity, the definition of natural, and the scope of biodiversity to be conserved.

Definition of biodiversity

The term biodiversity has many definitions that generally recognise three components – genes, species and ecosystems. Heywood and Baste (1995) note that in some cases the definition is distinct while on other occasions it is ambiguous, and make the following distinction (page 8):

> "Strictly speaking the word biodiversity refers to the quality, range or extent of differences between the biological entities in a given set. In total it would thus be the diversity of all life and is a characteristic or property of nature, not an entity or a resource. But the word has also come to be used in a looser fashion for the set of diverse organisms themselves, i.e. not the diversity of all life but all life itself".

In this document the authors have adopted the latter, looser meaning. Using elements from the Commonwealth Department of Environment, Sport and Territories (1996), Burgman and Lindenmayer (1998) and Main (1995), we have defined biodiversity as the variety of life forms including the different plants, animals and microorganisms. Biodiversity encompasses:

- genetic diversity - including the variation (and genetic distance) within and between populations of individual species and between different species, including taxonomic and phylogenetic diversity;
- species diversity - including both the number of different species and the relative abundance of each species within and between sites, habitats or geographic areas;

- structural diversity - including the variety of physical growth forms exhibited by organisms, particularly in relation to vegetation and its regeneration following disturbances such as fires or storms; and
- the diversity of living assemblages - that is, the variety of biotic communities and other living assemblages.

The key difference between this definition and those of the Commonwealth Department of Environment, Sport and Territories (1996) and Burgman and Lindenmayer (1998) is that we (always the authors in this document) have not included ecosystem diversity, but have substituted the concept of a diversity of living assemblages. This is for two reasons.

Firstly, biodiversity is shorthand for biological diversity. Therefore, we consider that a definition of biodiversity should only encompass biological entities, and not the abiotic components of the environment as implied by use of the term 'ecosystem'.

Secondly, when the term ecosystem diversity is used, ecosystem processes are then included within the definition of biodiversity. Again, some ecosystem processes include substantial abiotic components; therefore, this linkage seems inappropriate. Additionally, it is difficult to develop effective classification systems when different types of entities – in this case tangible biological entities and intangible processes – are included together.

Thus throughout this document the term biodiversity refers to the diversity of biological entities at a given place encompassing the four components described above. This approach is consistent with the conclusions of Callicott *et al.* (1999) who have reviewed a range of conservation concepts. The urge to include ecosystem processes and ecosystems in the definition of biodiversity seems to reflect a concern that people will neglect these important aspects of managing systems. In this respect, Callicott *et al.* (1999, page 25) suggested that the term "biological integrity" be used, and they cited the definition of Angermeier and Karr (1994) of this as:

> "Native species populations in their historic variety and numbers naturally interacting in naturally structured biotic communities".

However, in this document we restrict our use of biodiversity to natural biodiversity, and the management of ecosystem processes and the physical environment is dealt with through a rigorous treatment of threats as the key driver for operational management (see section dealing with 'Threats, goals and priorities' below).

Definition of natural

Hughes *et al.* (1992) define natural as "existing in or caused by nature". For us the key distinction is that natural things have not been brought into being through human (cultural) activity such as is the case with domestic livestock, agricultural crops, introduced weeds, feral animals, and exotic diseases. We recognise that there are difficulties with any definition of terms such as natural – see, for example, the discussion in Callicott *et al.* (1999). However, it is essential to be clear that, in this document, we are concerned with the conservation of natural biodiversity rather than domestic species and other biodiversity brought into being through the acts of humans. As noted previously (Footnote 1), throughout this document the term biodiversity should be read as natural biodiversity unless explicitly used otherwise.

The concept of natural is important in explaining the corporate goal, and it is accepted here that the goal activities of protection, conservation and restoration should occur within natural, or as near natural environments as practicable. However, under some circumstances it is also necessary to use non-natural environments – such as zoos and germplasm storage – to achieve the goal.

Scope of biodiversity to be conserved

Finally, the goal may be interpreted, at one extreme, as meaning that all existing elements of biodiversity down to individuals and populations will be protected, conserved and, where necessary and possible, restored. An alternative interpretation, adopted here, is that protecting, conserving, and where possible restoring the full range of natural biodiversity is the object of the goal. Thus, provided the full range of natural biodiversity is conserved and replicated, it may be acceptable to allow some natural populations and individuals to be unprotected.

Having explained these definitional aspects of the corporate goal, it is essential to examine constraints on achieving the goal in the Wheatbelt Region before elaborating how it is pursued. This discussion will show that the corporate goal is pragmatically an aspirational goal.

Constraints on achieving the corporate goal in the Wheatbelt Region

The values to humans of conserving wheatbelt biodiversity are stated above. These values are important not only at the regional scale, but also at national and international scales. For example, the South-west Botanical Province is considered to be a special terrestrial area (Department of the Environment, Sport and Territories 1994) at the national scale. At the international level, south-west Australia is considered to be one of 25 biodiversity "hotspots" (Myers *et al.* 2000). However, despite the high importance of wheatbelt biodiversity and the ostensibly strong support for its conservation, two groups of factors make it difficult to achieve the Department's goal.

Firstly, in the wheatbelt, development of agricultural land-use systems has profoundly changed pre-agricultural landscapes. Most of the natural vegetation has been cleared and converted to agricultural land and, generally, only small areas of natural habitat remain. In addition, clearing has been selective, and some habitat types, such as valley floor woodlands, were preferentially cleared. Typically, agricultural lands provide few ecological resources for native biota, and some species became extinct during the establishment of agriculture. Other species are declining in numbers and will become extinct over longer timeframes (Recher and Lim 1990, Saunders and Ingram 1995) as they struggle to survive in scattered fragments of their original habitat.

However, the impacts of agricultural land use go beyond loss of habitat. For example, plants and animals of Eurasian origin underpin wheatbelt agricultural systems. The introduction of these systems, along with their associated weeds and other biota – such as the mouse, sheep, fox and cat – have significantly affected remaining areas of natural habitat and their biota. Additionally, agriculture and its associated practices – including use of chemicals, fertilisers and new disturbance regimes – have profoundly changed natural systems and processes.

Modifications in natural systems arising from changes in wheatbelt land use will cause further extinctions in the native biota irrespective of conservation practices implemented. This is particularly so where broadscale ecosystem processes have been substantially altered, as is the case with hydrological processes (McFarlane *et al.* 1993, George *et al.* 1995). The most striking consequence is that increasing salinity threatens some 450 species of plants and numerous native animals with extinction (Keighery 2002).

Secondly, there is little or no emotional connection between the mostly urban population of Western Australia and wheatbelt landscapes. Evidence for this is the strong public interest in forest and coastal conservation issues in contrast with similar issues in the wheatbelt. Additionally, based on the direct experience of the authors, there is little understanding among rural or urban communities of the linkage between biodiversity conservation and their quality of life.

This is exacerbated by the fact that, where different land uses adjoin, there is generally tension between them irrespective of the types of land use involved. In agricultural districts biodiversity conservation is not a primary land use. Consequently, in most rural sub-cultures conservation is a low priority and sometimes viewed as an impediment to the business of earning a living from the land. In recent times this outlook has been compounded by very difficult seasons and the poor economic circumstances of many farmers.

Therefore, it is not surprising that, in comparison with other land uses in the wheatbelt, few human resources are allocated to biodiversity management and this constrains the level of achievement in conservation.

The combined impact of these points is that, in the Wheatbelt Region, the Department's corporate goal is pragmatically a vision, or aspirational goal. In this sense it is an important guide for departmental management activities and concepts. However, at the project level[3] it is essential to elaborate goals that both aspire to the corporate goal and provide pragmatic guidance for effective operational management. Thus while the corporate goal is accepted as an aspirational goal, more specific goals and objectives are developed at the project level.

The following section develops the concepts required to elaborate project goals. The steps in this process are to:

- identify the broad management strategies for biodiversity conservation in agricultural environments given the constraints described above arising from agricultural development, and the lack of connection between the mostly urban population of the State and the personal importance of biodiversity conservation. These strategies focus on the outcome or content component of goals;
- deal with issues related to the physical scale at which management is to be applied, that is, the definition of the physical extent or management unit over which management is to be applied; and
- account for time scale effects on management and goals. That is, to set the temporal scales over which goals should apply.

[3] Projects may be undertaken at a range of scales, over various timescales, and for a variety of purposes. The term project goal is used here in a generic sense to cover all goals below the aspirational goal. However, project goals will generally centre on the management of a key biodiversity asset (defined later) at a particular scale and for a particular time period.

Broad strategies for biodiversity conservation in agricultural environments

At a wheatbelt workshop in 1993, Main observed that:

> "Recently, it has become a legislative requirement that the public be involved when management plans are being prepared. Legislation or regulation requires that the aims, goals and requirements are specific – for example, 'preservation' may be a stated aim. This implies a static universe which can be preserved. Moreover, management plans require funds, and it follows that there is an expectation that those spending the money are accountable for achieving the legally specified goals. Yet, as indicated above, natural systems are hostage to chance events that are not readily accommodated in a legal system couched in terms of an ideal stable world. The potential difficulties should be anticipated by managers, who might sell their skills by emphasising that, even in a very fragmented, dynamic natural world, managers can retain the conservation values even if static preservation is not possible. Education to achieve a community awareness of what is biologically realistic is a prerequisite before sensible accountability can become a reality." (Main 1995).

Given the constraints on biodiversity conservation listed in the background above, these words have particular resonance. While this issue could have been discussed later in the document in conjunction with the section dealing with project goals (page 25), it has been introduced here as it provides the reader with a general understanding of what might be achieved for biodiversity conservation in agricultural areas, and as such seems suited to early discussion in a section dealing with goals in the broader sense.

Over the last decade, and particularly during the first six years of the Natural Heritage Trust (the Trust is described in Environment Australia 1999), many project goals involving biodiversity conservation have been couched in terms of conserving or enhancing populations of existing native biota although such goals are often not achievable. This has occurred for a range of reasons that are beyond the scope of this document, and it is accepted that State and national goals should contain a visionary element. However, the importance of correctly translating national and State level goals into useful and effective project goals is underlined.

Thus while the corporate goal or vision stated at the beginning of this section is a valuable starting point, it must be converted into useful goals at the project level. The first step in this process is to explore what broad management strategies are available in regions where remaining natural habitat is highly fragmented and reduced to a fraction of its previous extent. In such areas, the following six types of strategies for conserving biodiversity (based on Wallace 1998b and Wallace 2003) are proposed:

1. *Take no positive management action*. While the do nothing strategy may be acceptable, and sometimes it is a cost-effective management practice to take no on-ground management action in relation to particular areas, the Department always maintains a watching brief and responds to crises as they arise. Thus, from the Department's perspective, to do nothing is not acceptable given existing statutory responsibilities for biodiversity conservation.

2. *Ensure that the current threats to biodiversity conservation are not accelerated*. That is, take action only to the extent needed to ensure that the current rate of biodiversity loss in the wheatbelt is not accelerated by new human actions. The current rate of biodiversity loss is largely derived from past and continuing human actions; under this option the key task is to prevent any new human actions that will accelerate the current rate. In the Wheatbelt, for example, action will be taken to prevent the introduction of new environmental weeds and diseases, and to limit further destruction of natural habitat, all actions that will accelerate biodiversity loss.

3. *Slow the rate at which biodiversity values are being lost from agricultural areas*. It is widely accepted that species are still being lost from agricultural areas (Saunders 1989, Recher and Lim 1990, Saunders and Ingram 1995). It is also clear from our management experience that, in some places, it will not be practicable given current technologies and human resources to do anything but slow the rate of decline in the foreseeable future. Over much of the Wheatbelt Region this approach will be applied. However, this is quite different from the do nothing option, and is predicated on the assumption that slowing the rate of biodiversity decline today will deliver greater management options in the future and lead to conservation of more biodiversity in the longer term. Implicit is that innovations in technology and greater human resources may allow a shift from this option to (4) or (5) below. Some examples of specific management actions here include maintenance of regulatory activities,

basic fire protection, control of declared[4] plants and animals, and incentives for protection of privately-owned remnants.

4. *Take positive steps to conserve specific elements of the biota, generally threatened species or communities*. The shift from (3) to (4) is a quantum change in terms of resource demands and the timescales (decades) over which human resources must be applied. In the Wheatbelt Region this type of strategy is widely applied, particularly with respect to threatened species.

5. *Take positive steps to conserve all natural populations in an area*. In the Wheatbelt Region this strategy is difficult to achieve except where large areas of natural habitat remain. Usually, significant human resources must be applied over many decades to achieve this strategy in fragmented, agricultural environments. However, this approach is adopted with respect to specific landscapes in the Wheatbelt Region such as the Dongolocking and Wallatin areas (Figure 1). It is also applicable to very large reserves, such as Lake Magenta Nature Reserve (107,600 ha) (Figure 1). In other administrative regions of the Department that contain extensive areas of natural habitats, such as the forested areas of the South West and Warren Regions, and parts of the South Coast Region, pursuit of this management option is common.

6. *Reconstruct landscapes and their natural biota*. This strategy entails achieving (5) and then reintroducing those elements of the biota that have become locally extinct. In the Wheatbelt Region this strategy is pursued at specific sites with respect to mammals and several plants, with the 'Return to Dryandra' and Lake Magenta Nature Reserve fauna reconstruction projects being the most intensive programs.

While these broad strategies for biodiversity conservation have been elaborated in the context of an agricultural environment, they are relevant to biodiversity conservation in most situations, particularly where remaining natural habitat is fragmentary and extensively affected by human use. The options are particularly useful as an aid to defining the outcomes of project goals, a subject that will be returned to in the section 'Threats, goals and priorities'.

However, in goal formulation for operational management it is not enough to define outcomes, it is also essential to describe over what spatial scale and time period the specified outcomes are to be achieved. Thus the remainder of this section on goals deals with spatial scales (or physical units of management) and time scales.

Spatial scales and units of management

Goals need to be stated in relation to a spatial scale to set the physical boundaries for management. In practice, the goal and scale of management interact and influence each other, although goal setting should be pre-eminent. That is, management goals should drive the scale of management, rather than the reverse. There has, at times, been a tendency in natural resource management to select a scale of management irrespective of the goal to be achieved (see, for example, the discussion of regionalisation in Wallace 2003). There are three broad approaches to characterising spatial scales.

Firstly, one approach is to select management units that represent increasing geographical scale entities. For example, the sequence of: field (or paddock) level, farm level, catchment or landscape[5] level, regional and national level, and global level (Lefroy *et al.* 1993). In more biological terms, this could be represented as the sequence of plant association, remnant of natural habitat, landscape, bioregional, national and biosphere levels.

A second approach is to focus on levels of biological organisation with: genes, populations, communities or ecosystems, and landscapes being the most commonly used (Noss 1994). Such levels could be expanded to include bioregion and biosphere levels and Noss also identifies a series of biological structures as a hierarchy.

Finally, Noss also identifies functional hierarchies including the sequence: genetic processes, demographic processes-life histories, interspecific interaction-ecosystem processes, landscape processes and disturbances-land use trends. This hierarchy is a mixture of biological and physical processes, and while not specifically mentioned by Noss, this does raise the importance of selecting management units that represent the spatial scale at which processes need to be managed. For example, managing salinity in the wheatbelt often requires

[4] Declared plants and animals are those for which, in broad terms, there is a legal obligation to undertake some type of management action within Western Australia.

[5] Landscape is not a precise term. In this document the term is used in the general sense of Forman (1997) as "… a mosaic where the mix of local ecosystems or land uses is repeated in a similar form over a kilometers-wide area". The idealized section of a single unit of a wheatbelt landscape is shown in Figure 3 on page 20. A landscape in agricultural areas is where this unit is repeated with a similar pattern of land use, including natural habitats. From a biodiversity perspective, the distances over which significant species turnover occurs should govern the upper size limit of a landscape.

management to be at landscape or larger scales to encompass key hydrological processes. However, some organisms and populations are so irreversibly threatened by salinity that management will focus on the storage and management of germplasm from individual organisms. In yet other cases salinity may be managed at the scale of a single population by using engineering techniques (such as drainage) applied at the spatial scale of the population itself. These examples serve to underline that the spatial scale of management will vary depending on circumstances and, while influenced by critical biophysical processes, is not determined solely by them.

All these broad approaches to spatial scale are valuable to achieve specific purposes. Forman (1997 page 12) notes:

> "The planet is spatially subdivided in many ways, including political, economic, climatic, and geographic, depending upon human objectives".

The scales used by Forman are local ecosystem (such as a wood/remnant, which can be further subdivided to reflect its internal patchiness), landscape, region, continent and planet. This makes up a hierarchy:

> "selected because of its utility in meshing both human and ecological patterns, processes, and policies".

Therefore, the type of spatial scale used will often reflect a mix of characteristics best suited to the task at hand. From the standpoint of planning and implementing operational management, Wallace and Beecham (1998) found the following scales most useful:

- individual organisms;
- populations (often managed as a group that form a species);
- specific, identifiable areas of bushland [more properly, areas of natural habitat];
- landscapes; and
- bioregions and larger scales.

These management units represent a pragmatic mixture of geographic scale, biological organisation, and spatial units over which biophysical processes are managed. This choice of management units also reflects the fact that operational managers actually plan and implement activities at these various scales. Although it would logically be more convincing to use either one approach to scale setting, or some matrix of geographic, biological organisation and process management scales, the authors and current practice support the mix listed as being identifiable, physical entities with operational meaning. Their direct applicability in management makes them very useful. However, definitions of scale in relation to effective management units will continue to be developed and reviewed as this framework evolves. Each of the management units is briefly discussed below with particular reference to work by the Department in the wheatbelt.

Individual scale

Little management is undertaken in the Region at the individual scale. However, examples include cases where individual plants are identified as important because of their genotype, such as plants that are critically endangered. Another example is that of native species with commercial or other potential for revegetation. Often individual plants in this category are individually managed and are marked for seed collection and related work.

Population scale

Far more common is management action at the population scale. Most activities in the Wheatbelt Region at this scale involve actions, based on interim recovery plans, to protect populations of critically threatened species. Other management activities at this scale include the control of problem species. For example, management of damage caused by western grey kangaroos is generally implemented at the population level, often to protect a specific landholder. In most cases populations are managed in a way that conserves species, and it could be argued that this scale would be better considered as the species scale. However, given the pre-eminent focus of management on specific populations, these have been considered here as the scale of management.

Individual remnants of natural habitat

Historically, most management and planning work within the wheatbelt focused on individual remnants of natural habitat and adjoining lands. For a range of management activities – for example, rehabilitation works, aspects of fire protection, recording of resource information and weed management – this is still often the most convenient management unit for planning and implementing operational actions. Therefore, this remains an important scale of management today, particularly where the key management strategy is to slow the rate of biodiversity loss. To date local community groups have also tended to focus their efforts at this scale.

Landscapes

Where the management of metapopulations for viability, or ecosystems/communities (for example, Toolibin Lake freshwater system), or subregional samples of the biota (for example, Dongolocking and Lake Magenta Nature Reserve complexes), or broadscale environmental processes such as salinity are important, it is imperative to plan action at much broader scales such as the landscape. Management of large conservation reserves, particularly those over 25,000 hectares, is also best considered at landscape scales. As can be seen from the examples, sometimes landscape management units are used as they best encompass the biological asset to be managed, and sometimes because units of this size are necessary to manage critical processes. However, note that many operational activities at this scale, and the next, will involve management of populations.

Bioregional and larger scales

Finally, even broader scales, including bioregional, State, national and global scales, are important for particular forms of planning and action. Examples include the conservation of adequate and representative samples of the native biota within bioregions; and management of the many migratory species that cross bioregional, State and national boundaries. These broader scales are also an important context within which policy and resource arrangements are developed. In contrast, such scales are rarely effective for planning on-ground implementation[6].

Currently the boundaries of the Interim Biogeographical Regionalisation of Australia (IBRA) (Thackway and Cresswell 1995) are being tested as a basis for management planning. Already it is apparent that these bioregional boundaries provide a useful basis for collating and analysing information, particularly for comparisons and planning at national and state levels. They also provide a valuable context within which to define the representativeness component of biodiversity assets (see next section).

However, landscape and smaller scales are generally more useful for planning and implementing on-ground, management action. This is because:

1. There are many important attributes – including the distribution of many species, physical boundaries such as catchments, and social and political boundaries – that do not coincide with IBRA regions. While similar constraints apply to any specified boundary, anomalies generally decrease with decreasing size of the management unit. At the same time, geographic units selected for management must be sufficiently large to encompass the biophysical processes critical to achieving the management goal.
2. While it is practicable to manage some nomadic and migratory species at regional, national, and even international scales; it is rarely feasible to manage complex communities and their environments – including human interactions – at scales larger than a landscape.
3. In agricultural landscapes with highly fragmented natural vegetation, the development of manageable landscape units is related more to the amount of habitat and its arrangement than it is to relationships with bioregional boundaries. In some cases important, but comparatively small landscape units – for example, Dryandra Woodland – are split by major bioregional boundaries.
4. It is important to recognise existing social units and their constraints on planning and on-ground action. The greater the number of social units dealt with, the more difficult it is to plan and implement management. These issues limit the upper size of landscapes that can be effectively managed with a given level of human resources (financial, personnel, etc.).

Consequently, management at regional and broader scales is generally, for the Wheatbelt Region's staff, a planning rather than operational process. For example, while the management of some broad ranging species such as the malleefowl (*Leipoa ocellata*) (Benshemesh 2000) and programs such as *Western Shield* (Department of Conservation and Land Management 2001a), are planned at a regional scale, operational work is generally undertaken in the context of a specific conservation goal planned and implemented at the population, reserve or landscape scale. Thus in the Wheatbelt Region, while the regional scale is important for developing and providing expertise, strategic direction, communication programs, generic solutions, political strategies, supervision, technical support, administrative support and management concepts including some degree of priority setting; it is rarely a scale at which on-ground management is planned.

Summary

In summary, the key management units used in the Wheatbelt Region are the population, remnant natural habitat and landscape scales. Where

[6] There are many issues concerning planning and scale. Wallace (1998c) comments on a range of issues including the importance of letting management goals drive the scale of action, and both he, and Saunders and Briggs (2002), have discussed the miss-match between administrative, land use and ecological boundaries. While important, these issues are beyond the scope of this document.

necessary, planning and action are also undertaken at regional and larger scales. These units best reflect the:

- organisational complexity and spatial dimensions of biodiversity entities (or assets, see below) managed;
- need to manage at spatial scales appropriate to key processes influencing the management goal. It will be argued below that an analysis of threats to goal achievement is the best method for taking into consideration where biophysical processes need to be better managed (see also Appendix 1); and
- socio-cultural aspects required to deliver cost-effective management.

Geographically, the goal and scale concepts described above lead logically to the definition of a range of management units in the Wheatbelt Region. These units provide the spatial structure for more precise goal setting and planning and reflect the biodiversity entities to be managed.

Time scales of management

The importance of time as an aspect of goal achievement is underlined in the wheatbelt by the long natural cycles and extended lag times for the expression of change. For example, the development of large nesting hollows may take as long as 130 (Saunders *et al.* 1982) or 150 to 200 years (Rose 1993). Also, it is predicted that in the eastern wheatbelt salinity will not reach full expression for over 200 years (Agriculture WA *et al.* 1996). There are obvious difficulties conceptualising and applying management over such long periods. We simply do not have the knowledge, predictive ability or institutional arrangements to manage over these time frames.

Practically, then, we plan over quite short time frames, typically from three to 50 years. It is essential that managers specify a time frame for each of their management goals, and recognise the implications of planning inside the return times of natural and other cycles. This can be partially achieved by stating assumptions, particularly within threat analyses (see Table 2, page 21). At a broader level, it is important that those engaged in managing biodiversity – whether their functional area is policy, planning, research or operations – understand the limitations imposed by the conflicts between the time scales of natural cycles and those of human planning and management.

Summary

In this section we have dealt with the aspirational goal of the Department for biodiversity conservation and the underlying human values. The constraints on achieving this goal in the Wheatbelt Region have been described, as have the broad strategic options for conservation that result. These broad options effectively describe the range of outcomes that can be achieved through project goals. The section closed with a discussion of the most useful spatial scales (or management units) over which goals may be applied, and the need to couch goals in terms of time scales and the limitations this imposes. Thus there is no repetition or re-writing of the Department's goal at the regional level. Rather, the Department's goal is used as an aspirational goal at the regional level, and drives the development of project goals, most of which are attached to specific units of management (such as particular individuals, populations, remnants of habitat, or landscapes). However, before developing the more specific goals required for projects, it is essential to understand the actual biodiversity assets to be managed and the use of threat analyses in setting priorities. These are the themes for the next sections.

Finally, from the foregoing discussion it is clear that the corporate or aspirational goal with which we began should also be couched in terms of both a management unit and time frame. In this case, the management unit is the State of Western Australia, and the temporal period over which the goal is to be addressed is three years, the life of the current Corporate Plan (Department of Conservation and Land Management 2002).

Biodiversity assets

Having established a goal, along with its associated spatial scale and temporal duration, the next step is to describe the entities that must be managed to achieve it. Given the goal is couched in terms of protecting and conserving natural biodiversity, the entities that need to be managed must be the tangible elements of biodiversity. The term used here for these entities is biodiversity assets. A biodiversity asset is a living entity – such as a single organism, a population of organisms, or an assemblage of living things – that is considered valuable to humans in terms of the values described in Appendix 2. Given the aspirational goal used here, and the wide range of human values attached to this goal, the sum total of biodiversity assets is taken to be all natural, living organisms of the State.

One approach to characterising biodiversity assets is to list the components of biodiversity. The list in *The National Strategy for the Conservation of Australia's Biological Diversity* (Commonwealth Department of Environment, Sport and Territories 1996, page 7) provides an example of the range of components that may be used:

a. "ecosystems and habitats that contain high diversity, large numbers of endemic or threatened species, or wilderness, that are required by migratory species, that are of social, economic, cultural or scientific importance, or that are representative, unique or associated with key evolutionary or other biological processes;
b. species and communities that are rare or threatened, that are wild relatives of domesticated or cultivated species, that are of medicinal, agricultural or other economic value, that are of social, scientific or cultural importance, or that are of importance for research into the conservation and sustainable use of biological diversity (such as indicator species);
c. described genomes and genes of social, scientific or economic importance".

As can be seen, this listing represents a range of biodiversity characteristics that reflect compositional (for example, ecosystems, species and genomes) and functional aspects. Furthermore, the functional aspects include functions in relation to human values (for example, cultural and economic importance) as well as ecosystem processes (for example, "associated with key evolutionary or other biological processes"). This is a very broad listing of biodiversity components and it is useful to explore how this list can be refined and sharpened. There are a number of ways to do this.

Firstly, because this document is couched in terms of a specific aspirational goal, and the connection of this goal with human values has already been made (Appendix 2), it is redundant and confusing to again include these values at a lower level. Thus while biodiversity assets must reflect the human values driving the aspirational goal, human values are not themselves the biodiversity assets to be managed to achieve the goal. Also, as stated above, the goal is couched in terms of conserving things, not processes[7] or values. However, note that this may well change with a change in goal – emphasising again the importance of establishing a clear goal.

Secondly, although it is vital to manage ecological processes to achieve the aspirational goal and conserve, protect and restore the assets, the processes themselves are not the biodiversity assets. In this sense we manage the processes to protect the assets to achieve the goal to deliver human values. (There is also substantial debate about the role of biodiversity in maintaining ecosystem processes. See, for example, Doherty *et al.* 2000 and Main 1992a.) Furthermore, as discussed previously, ecological processes include abiotic elements, and it is anomalous to include these in a definition of biological diversity. Thus we can remove the remaining functional elements from consideration as biodiversity assets.

This second point raises an important question about whether keystone species, focal species, indicator species, umbrella species, etc., are potentially biodiversity assets. It is proposed here that while they may be valuable tools for managing processes to conserve biodiversity assets, and in this regard are asset surrogates, they are not themselves assets except as specific biological entities. In contrast, charismatic and icon species could be considered biodiversity assets because they reflect, through the aspirational goal, special values that humans may wish to conserve.

One additional asset type needs to be considered. Sometimes the habitat of a biological entity – for example, of a migratory species – is considered as an asset. However, the habitat is managed to protect the

[7] The definition of biodiversity is critical here – see the relevant discussion in the previous section of the document. Some people have considerable difficulty with this approach to processes as they assume it downgrades their importance. The authors agree that it is vital to maintain processes to protect and conserve biodiversity assets. However, it is still biodiversity assets that are the focus of the goal. In the final analysis, if we maintain processes and lose some of the assets, we will have failed to achieve our goal if that goal is couched in terms of maintaining living entities. In this framework, the importance of managing processes is picked up in the threat analyses that drive operational management.

migratory bird. That is, the bird is the asset, not its habitat. In a similar vein, specific types of land tenure, such as conservation reserves, are biodiversity assets because of the living assemblages they contain, not their tenure. That is, land tenure is a management tool, not an asset.

To summarise, biodiversity assets are those natural individuals, populations, and living assemblages that must be conserved or protected to achieve the aspirational goal, which in turn reflects (or should) the human values that underpin the goal. These assets will include, but are not restricted to (grouping of examples consistent with the structure provided in the definition of biodiversity):

Genetic diversity

Individuals showing specific genotypes or alleles of high conservation interest are the focus in this category. Note that there is also considerable opportunity value through commercial interest in this area. However, it is assumed that most genetic diversity is conserved through the following categories.

Species diversity

- Rare[8] plants and animals. Note that threatened species are not included here, as such definitions ultimately reflect the viability of the particular rare species. A rare species, if management assures its viability, is not threatened. The importance of separating current importance and viability when defining importance for biodiversity conservation is an issue returned to later in the document.
- Populations of plants or animals at the edge of their natural range.
- Populations of plants or animals that are uncommon phenotypic or genotypic variants.
- Relictual species (for example, Gondwanan biota), including species of high phylogenetic interest.
- Endemic species.
- Icon species. For example, conservation of the koala and western grey kangaroo is of high public interest.
- All other species. Note that it is assumed that these are dealt with by effective conservation of living assemblages, particularly representative landscapes (see below).

Structural diversity

To date, no biodiversity assets have been specifically defined within this category.

Diversity of living assemblages

- Rare ecological communities.
- Special living assemblages, such as samples of local ecotypes, sites with a high level of endemism, unusual associations of plants, sites of unusually high species diversity, and so on.
- The biota of remnant natural habitats, such as patches of vegetation, isolated wetlands, and granite outcrops.
- Representative landscapes. These are significant samples of sub-regional or regional biotas. To capture a range of biodiversity that reflects the original, pre-clearing local biota, the most important representative samples will generally be landscape units containing a significant proportion of natural habitat. This is further emphasised by the rapid turnover of species in the south-western agricultural region (Burgman 1988). Using Burgman's 15-kilometre turnover figure as a guide, it would be preferable to have representative samples contained within areas of about 20,000 hectares. That is, circular shaped units with radii of 7.5 kilometres that sample communities at a spatial scale smaller than the turnover rate. Note that this conclusion is reached regardless of viability, although such landscapes also have important viability attributes, an issue covered later (see, in particular, Appendix 3). Also, it is useful to note that IBRA regional categories and information will play an important role in helping to define what representative means in an operational sense. Finally, these units will be the key assets for conserving samples of species and genes/alleles that are currently abundant and common.

Often more than one of these biodiversity assets will occur in the same locality, particularly at the landscape scale. It should also be noted that each of these assets readily links with one or more of the management units developed in the preceding section. In the Wheatbelt Region, operational management focuses on rare species, rare communities, remnant natural habitats and representative landscapes.

The list of biodiversity assets, their key characteristics, their relative importance in relation to the aspirational goal, and the selection criteria that should be used to rank them in importance are all matters that require further development and

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[8] The term rare is used here in the general sense, not with the specific statutory meaning of the *Wildlife Conservation Act 1950*.

research. Given that there is a separate project presently addressing these issues, they are not considered further here. However, it is critical to resolve these questions, and the above list is only a starting point. It should also be noted that our knowledge and management of biodiversity assets are biased to vertebrates and plants, with other life forms, such as invertebrates and fungi, receiving too little attention.

Finally, an important check on the linkages between human values, aspirational goals and assets is to confirm whether the specific biodiversity assets selected will deliver the needs expressed through human values. If they do not, then either the aspirational goal does not sufficiently reflect human values, or the biodiversity assets have been inadequately defined. Assessed in this way, it is apparent that there are omissions in the list of assets above. For example, while roadside vegetation is generally important for biodiversity conservation, at specific sites it contributes little to achieving the aspirational goal, but may deliver important aspects of amenity values. These latter values have not been reflected fully in the list of assets described above even although amenity values were linked to the aspirational goal. Furthermore, while conservation of the listed assets, particularly living assemblages, will contribute many ecosystem services, not all services are represented by this list of assets, an issue that needs to be addressed. This shows the importance of better linking human values, aspirational goals and biodiversity assets.

Having now examined the matter of goals (why we manage) and what needs to be managed (biodiversity assets) to achieve the aspirational goal, we are in a position to develop that part of the framework dealing with how we go about operational management.

Threats, goals and priorities

Threat analyses and conservation management

Management for biodiversity conservation fundamentally involves preventing the loss of natural biodiversity (or biodiversity assets) by managing biophysical processes. Even reconstructing biodiversity – for example, by translocating native mammals to an area from where they have become locally extinct – is largely about ensuring there are sufficient representative populations to secure long-term conservation of populations and communities. As explained in Appendix 1, where the functioning of an environmental process endangers a land use such as biodiversity conservation, this may be described as a threat to that land use. If there are no threats, actual or potential, to biodiversity conservation, then there is no reason for management. Thus biodiversity conservation in an operational sense involves the management of threats to biodiversity assets to achieve specific conservation goals. Consequently, the concept of threats and their management is a very important tool in operational management.

The notion of threats has been widely used in conservation management. See, for example, Stephens (1992), Young and Millar (1997), Burgman and Lindenmayer (1998), Salafsky and Margoluis (1999), and The Nature Conservancy (2000a, 2000b). Main's (1992b) ideas for managing to maintain biodiversity in the face of uncertainty are also highly relevant, as are a number of other papers including those by Possingham and Shea (1999) and Possingham *et al.* (2002). Used effectively, these concepts allow biodiversity conservation goals and operational management strategies to be clearly linked.

However, the process for analysing threats in relation to biodiversity assets is not well explained in the literature examined by the authors. Appendix 4 provides a discussion of this issue and the approach and definitions adopted in the Wheatbelt Region. Arising from this work, officers in the Wheatbelt Region developed the following categories of threats. While there are other ways of structuring threats, this arrangement has proved most valuable for analysing threats for conservation planning including works programming. Note that the management issues provided with each threat are examples only – they are not intended as comprehensive lists.

1. *Altered biogeochemical processes (at landscape or larger scales)*: Management issues include:
a. hydrological processes, particularly salinity and waterlogging, and negative impacts of drainage;
b. nutrient cycles, including eutrophication; and
c. carbon cycle and climate change.

2. *Impacts of introduced plants and animals*: Management issues include:
a. weed control;
b. control of feral pests;
c. preventing new introductions of damaging species;
d. competition for shelter and food; and
e. grazing of remnants by stock.

3. *Impacts of problem native species*: Management issues include:
a. the dramatic increase in numbers of some parrots, due to habitat change, resulting in grazing damage and competitive exclusion of some other native species; and
b. defoliation by scarab beetles and other damage by excessive numbers of native herbivores.

4. *Impacts of disease*: Management issues include:
a. dieback (*Phytophthora* spp); and
b. armillaria.

5. *Detrimental regimes of physical disturbance*: Management issues include:
a. fire regimes that may lead to local extinction of one or more species;
b. cyclones; and
c. drought.

6. *Impacts of pollution*: Management issues include:
a. herbicide use and direct impacts on plants, including effects of fungicides;
b. pesticide surfactants and impacts on vertebrate reproduction; and
c. oil and other chemical spills.

7. *Impacts of competing land uses*: Management issues include:
a. recreation management;
b. management of agricultural impacts;
c. management of consumptive and productive uses (wildflower cutting, timber cutting, etc.);
d. management of illegal activities, such as rubbish dumping, non-approved consumptive uses, etc.; and
e. management of mines and quarries on bushland.

8. *An unsympathetic culture*: Management issues include:
a. negative attitudes to conservation; and
b. poor understanding of biodiversity conservation values and their contribution to human quality of life.

9. *Insufficient ecological resources to maintain viable populations*: The management issue here is:

Table 1: Scale of management and key management tasks

Individual	Population	Individual remnants of natural habitat	Landscape	Bioregion, State, national and global
Management of critically endangered genotypes and those of high commercial interest.	Management of threatened species, and species subject to commercial and consumptive utilisation.	Management of small, living assemblages. Unless managed as part of a landscape network, the main task is slowing the rate of biodiversity decline.	Management of threatened communities and representative samples of regional biota. For highly cleared landscapes, main task will be slowing the rate of biodiversity decline.	Apart from strategic planning and policy tasks, management at this scale focuses on connection between landscapes with particular emphasis on recolonisation and management of wide ranging, migratory and nomadic species.

Ensuring that, if threats (1) to (8) inclusive are held constant, there are sufficient resources (see Table 7 of Appendix 4) to allow viable populations of organisms to persist. This includes sufficient space for habitat replication so that disturbance regimes (see threat (5) above) may be managed. However, the basic resources are food, water, oxygen, shelter and access to mates. Creating buffers and corridors, habitat reconstruction, and regeneration of degraded areas are important management techniques in this context.

These threats apply across all management scales. Table 1 describes the key management tasks at each scale of management.

The document to this point has defined why we are managing (aspirational goals and human values), what we are managing (biodiversity assets) and broadly how we will manage (threat analyses). In the next section these ideas are developed further into a framework for setting management priorities.

Setting management priorities - background

Managers set priorities against a range of objectives at a variety of scales. Generally, at State and smaller scales, these decisions may be readily grouped into one of four types.

Firstly, there are important questions about priorities between different types of biodiversity assets. For example, should more management resources be allocated to rare species, or to landscapes supporting representative samples of regional biotas? Ideally, sufficient human resources should be allocated to allow all important biodiversity assets to be effectively managed. Such an approach is most consistent with the aspirational goal described above. However, the realities of available human resources mean that decisions of priority between assets are made. Historically, rare species have been accorded a high priority as they represent the component of biodiversity most obviously at risk. More recently in the south-west, the importance of managing landscape and broader level threatening processes, such as salinity, have challenged this conventional approach to priority setting.

Methods for allocating priorities between assets are currently being evaluated in a separate project at State level, and therefore the topic is not dealt with further except to underline the great difficulty of establishing priorities between groups of very different types of assets. This has always been a difficult task. For example, biodiversity scientists from a range of disciplines concluded at a 1987 workshop that:

> "a significant component of major decisions [between different 'themes'] will continue to reflect the subjective view of senior staff" (Wallace 1988).

Secondly, and most commonly, there are important questions about which assets, within a class of assets, should be managed as a matter of priority. Key questions are: Which populations? Which landscapes? Which natural habitats? Note that setting priorities at the largest relevant unit for a particular asset will also set priorities at smaller scales. For example, if priorities are established for managing threatened species or representative landscapes at a State level, then these priorities will naturally flow through to the regional and sub-regional levels as a sub-set of State priorities. (Note, however, that at sub-regional scales there may be additional priorities to meet local needs.) This subject is a key question affecting on-ground action and is dealt with below.

Thirdly, once sites have been selected for management action, then priority management strategies and actions must be established for each site. Again, this is a key task for operational managers at regional and smaller scales, and is dealt with below.

Fourthly, there are also important questions of priority, generally asked at larger than regional scales, concerning priorities for research, and cultural and technical development. For example, for salinity management in the south-west agricultural region there are presently important questions about the relative allocation of human resources to research and development of recharge control[9] versus discharge management[10]. These questions are very important, however, the project mentioned under the first item is also working on this issue, and therefore the topic is not discussed further here.

As the first and fourth questions are currently being examined by a separate project, only the second and third questions are examined in detail in this document. That is, the following two sections focus on:

1. setting priorities among sites from within a single class of biodiversity asset – such as representative landscapes; and
2. setting priorities among alternative management strategies to manage a particular biodiversity asset.

Before dealing with these two topics, it is important to distinguish the importance of a biodiversity asset today (in relation to the aspirational goal) from how its value might be construed in terms of its viability in future. These two aspects of assets are distinguished throughout the remainder of this framework. The main reason being that, if viability and current importance measures are mixed, people usually downgrade assets that they perceive as being of low viability, irrespective of their actual current importance. Thus the focus of management may prematurely be shifted without the actual importance of assets being fully assessed. This issue is exacerbated by the fact that a range of issues, including changes in human resources and technology, impinge on viability, and these capacities may change dramatically within short time periods. For example, the capacity to manage a wetland threatened by salinity can change dramatically from minimal to high with a single decision to shift significant financial resources to management. Therefore, while management priorities need to take into consideration both current and viability values, it is very important to separate them at the beginning of priority setting processes.

Setting priorities among sites

The process to establish priority sites within any one of the key biodiversity asset groups – such as populations/species, rare ecological communities, living assemblages in remnants of natural habitat, or living assemblages in landscapes – is broadly the same. In each case, to set priorities we need to, in the context of the aspirational goal, combine an assessment of:

a. current values of assets in relation to the aspirational goal;
b. biophysical viability of assets;
c. knowledge and technical capacity to manage threats; and
d. socio-political capacity to manage threats.

The process for establishing priorities within one class of biodiversity asset – representative landscapes (that is, living assemblages that provide a representative sample of sub-regional or regional biotas) – is described below to explain (a) to (d). As already noted, the general process is similar across all biodiversity assets. Representative landscapes are deliberately used as the example because they are not well understood, and the opportunity has been taken in this document to deal with some of the key issues.

Current asset value

The importance of separating current asset value and asset viability is explained above. In this section, the current importance of representative samples of sub-regional or regional biotas is explored. The key issue here is to select living assemblages that effectively represent sub-regional biotas.

While there has been considerable work on selecting conservation areas – see, for example, the review by Prendergast *et al.* (1999) and the work by Faith *et al.* (2003) – this has largely been based on selecting minimum areas required to capture diversity with a minimum amount of replication. In relation to ranking individual conservation reserves, Safstrom (1995) concluded that:

> "iterative selection algorithms are not a useful tool for ranking reserves in the central wheatbelt due to lack of a complete data set and high diversity, endemism and species turnover" (page 37).

This comment is equally applicable to landscapes across the agricultural region. Note also the issues of viability raised below and discussed in detail in Appendix 3.

Accepting the points made in the above preamble, the question that needs to be asked is: How do you select representative landscapes that best represent the pre-agricultural biota? There are three aspects of this question that are important here.

Firstly, Burgman (1988) found in his study that there is significant plant species turnover in the eastern half of the Roe Botanical District, and that one needed to have conservation reserves every 15 kilometres to

[9] Such as development of new industries based on perennial plants to replace annual systems that leak water.
[10] Such as deep drainage.

sample this diversity. Assuming this figure is broadly applicable across the agricultural region, then landscapes that are likely to retain representative samples of living assemblages need to be about 20,000 hectares in size (that is, a circle with radius 7.5 kilometres) or smaller, and contiguous across the region. (However, note that the findings of Burgman cannot be applied to all taxa. For example, it doesn't fit well with the wetland situation where many aquatic species occur very infrequently but are widely distributed (personal communication Stuart Halse)).

Secondly, given the rapid turnover and complex patterning of geomorphology (McArthur 1992) and related habitats, within these landscape units there will need to be a significant area of remaining habitat to sample across the catena (Figure 3) and thus represent genetic, species, structural and living assemblage diversity. The catena shown in Figure 3 occurs in related forms throughout the wheatbelt, with an estimated minimum area of some 10,000 hectares being required to capture a full range of the soil-landform types (the precision of this estimate needs to be researched). This sets a lower landscape scale of some 10,000 hectares.

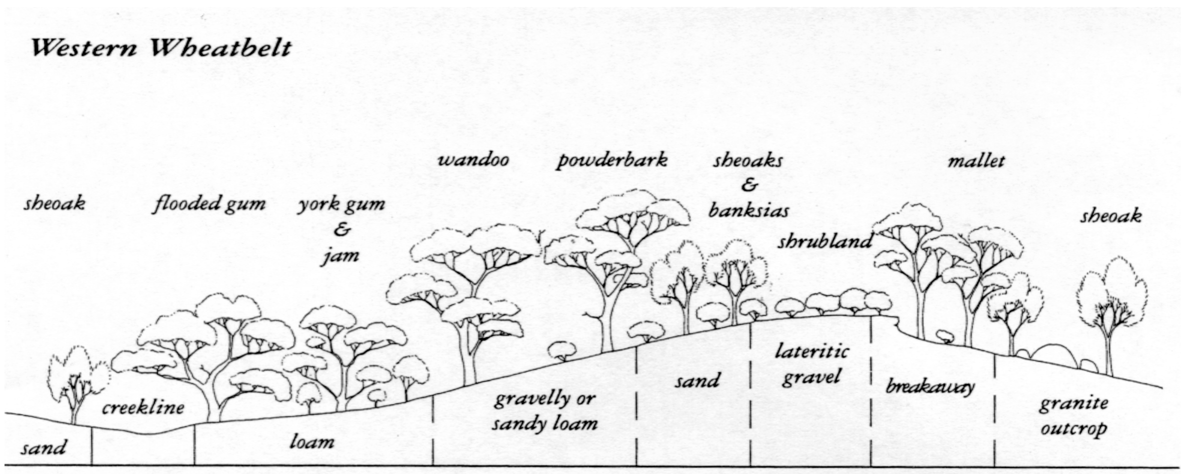
Crudely working this through, in Figure 3 there are eight landform/soil components across the catena, each of which typically carries a particular range of vegetation and other habitat components. One could expect at least three major variations within each of these eight landform/soil units, thus giving 24 elements overall. Assuming, conservatively, that one needs a minimum of 100 hectares per element to capture species and genetic diversity, one would need a minimum of 2,400 hectares for each landscape unit of 10,000 hectares to contain a representative sample of the biota. This equates to about 25 per cent of the landscape unit, and given the turnover and species diversity of wheatbelt landscapes, is a very conservative estimate.

Thirdly, the probability of a landscape sample of the biota being representative will increase with the area of the landscape contained within natural habitats. Thus while the rough estimates above suggest that some 25 per cent of a 10,000 hectare landscape needs to be in natural habitat to provide a reasonable, representative sample of biota, the effectiveness of this sample will be improved if the proportion of natural habitat is increased, and conversely, decreased with less natural habitat (assuming identical effectiveness of sampling across the catena). Therefore, the area of natural habitat remaining in a landscape (minimum size 10,000 ha) can be used as a crude index of that area's relative value as a sample of the local, native biota.

Thus using the same analysis described in Appendix 3, representative landscapes may be selected. These can then be ranked in terms of current importance on the basis of a number of criteria including amount of natural habitat remaining, diversity of habitats, and how well the habitats are currently conserved. These three aspects provide the initial criteria for assessing the current value of representative samples of regional biota. While they may be used to make an initial ranking of landscapes in terms of current values, there is work in progress within the Department to develop more sophisticated ranking processes. For example, staff are assessing a range of measures apart from area measures of habitat types. These include using numbers of vegetation associations and numbers of threatened species as additional measures of diversity.

Although the criteria used for evaluating the current importance of a biodiversity asset will differ from asset type to asset type, the importance of assessing current value applies equally to all asset types. Having decided which assets are most important in terms of current value, the next question relates to the long-term viability of these assets.

Figure 3: Idealized cross-section of Wheatbelt landscape. [Taken from Bamford 1995, page 12]



Biophysical viability of assets

Having evaluated which assets within a class of biodiversity assets are most important for achieving the aspirational goal, the next question relates to assessing the probability that the attributes of these assets will be carried into the future. Threat analyses are the key evaluation mechanism for this task. To do this, a threat analysis needs to be conducted for each asset in the context of a particular goal. This is best explained by a specific example.

At Dongolocking where the goal is "to conserve the existing biota of a landscape for 50 years", a threat analysis was undertaken (Table 2) based on an earlier version of the threat categories listed above. This included an analysis of the probability that any one category of threat would prevent the goal being achieved, that is, will cause local extinction of a species within 50 years.

Table 2: Dongolocking Project – probability of specific threats causing local extinction (adapted from a much larger analysis of threats in Wallace 1998a).

Threat	Method of calculating probability (p*)	p*
Insufficient habitat resources and reproductive opportunities to maintain viable populations	Most of the threats listed below will interact in a way that intensifies the problems related to insufficient habitat resources. This is taken into consideration where relevant. However, it is also possible that 'relaxation' of species at Dongolocking is not complete. There may, for example, already be populations in which deaths outnumber births, or in which recruitment has ceased. The threat of this occurring is comparatively high – estimated at 0.06. This threat also takes into consideration that there are some species within the Dongolocking area, such as wedge-tailed eagles (*Aquila audax*), that require very large areas to maintain viable populations, or that are nomadic or migratory. Events outside the study area will affect the local persistence of these species irrespective of management within the study area.	0.06
Introduction of new major weed	Since settlement in 1829 about 1,000 species of plants have been introduced and now grow wild in Western Australia (Hussey *et al.* 1997). Major environmentally damaging weeds have been introduced as recently as the 1990s (e.g. *Kochia scoparia* in 1990). Hobbs (1993) has calculated that the rate of introduction of new species has not slowed in the period 1880 to 1980. Also, many weeds have a long period persisting at a low level before they dramatically increase and become a problem. Therefore the likelihood of further, environmentally-damaging weeds being introduced or suddenly expanding within 50 years is high. The probability of a new environmental weed being introduced or expanding and causing the local extinction of a native species is calculated to be 0.05. Assumptions: • rate of introductions will remain constant or increase. There is no reason to believe that the introduction rate will decrease from that described by Hobbs (1993). In fact, given the interest in bringing new woody species and perennial grasses into the environment for production and landcare reasons, it is reasonable to assume that the introduction rate will increase, particularly as salinity increases and people attempt to bring in very robust species, and as 'miracle' species are promoted. Probability of new weeds occurring therefore considered to be 1.0. • probability that a major environmental weed will have sufficient impact to cause the extinction of at least one native species within 50 years, either by direct competition or by habitat alteration is quite low (although high over, say, 100 to 200 years). Probability assessed to be 0.05. [Note that this estimate is conservative. Between 1947 and 1985 13 per cent of 463 exotic grasses and legumes introduced into Northern Australia became major weeds (Lonsdale 1994).]	0.05
Fire	A very large fire burnt through most of the Dongolocking area in 1927. Research is inadequate, but there is no record, to date, of two such large-scale fires affecting one location in the western wheatbelt. Therefore it is assumed unlikely to occur more frequently than once in 200 years, and that the probability of such a fire causing local extinction is 10 per cent. Therefore probability of fire causing an extinction in next 50 years is calculated as 0.005 x 50 x 0.1 = 0.025.	0.025

*p = probability of a single species extinction occurring within 50 years.

The predictions in Table 2 are very rough estimates due to our lack of knowledge concerning life histories, ecosystem function, and population viability. Also, the synergistic and antagonistic interactions between threats are rarely known, and difficult to account for.

Despite these difficulties, the process of setting probabilities does provide a useful basis for ranking threats in terms of their likely impacts. The advantage of ascribing probabilities, as opposed to using categories such as 'high' and 'low', is that to generate a probability requires managers to state the assumptions and knowledge upon which probabilities are generated (see Table 2). While this is a much more demanding process than 'expert' assessment, it forces a more incisive analysis of threats and provides a more substantial foundation for future analysis and research. The approach also provides a starting point for generating alternative hypotheses that might be used in experimental management in the terms described by Holling (1978).

However, Bailey *et al.* (1992) have, in the context of environmental impact assessment, pointed out that the identification of an environmental impact, even if not accurately predicted, can provide the conditions for effective environmental management. Morrison-Saunders and Bailey (1999) underlined this point and stated that:

> "simple impact identification may be all that is needed in order to put in place strategies to avoid impacts outright or to manage those that cannot be completely avoided" (page 293).

Thus even a simple threat analysis may provide a useful basis for on-going management. This point notwithstanding, a probability analysis of the type shown in Table 2 provides a better basis for priority setting, a topic that will be returned to below.

The higher the probability that a threat or threats will prevent goal achievement for a particular landscape, then the lower is the viability of the landscape biota in question. This process, therefore, provides a method for ranking landscapes according to their viability in relation to biophysical threats. While the example here is based around a landscape management unit, the same process can be used at any scale and for any type of biodiversity asset. Already the concept of threat is used for defining threatened plants and animals and ranking them for management action (for example, Brown, Thomson-Dans and Marchant 1998). However, the set of threat categories used is narrower than described here, and probabilities are not explicitly used.

While it would be desirable to assess all biodiversity assets using a comprehensive threat analysis similar to that used in the Dongolocking work, this is not currently practical given the available human resources. Therefore, simpler methods are used to assess the viability of assets across large areas. Appendix 3 describes one method that has been used in the wheatbelt for comparing the viability of representative landscapes. Such methods allow large data sets of biodiversity assets to be reduced to a more manageable size. Managers can then apply a more comprehensive analysis to a sub-set of assets in priority setting processes.

In the wheatbelt there are not enough management resources to manage all landscape units intensively. Therefore, the authors concluded that it is preferable to allocate a greater proportion of management resources to areas that either are inherently viable, and thus are most likely, with management, to carry their values into the future; or are likely to become viable with comparatively high (but affordable) levels of management. Landscapes that are not – given existing biophysical threats, technologies and human resources – likely to retain a significant proportion of their biodiversity into the future are, therefore, a lower priority for management.

This situation may change in the future with new technologies or additional human resources, or both, so placing a landscape to a lower level of management is not a death sentence, nor does it necessarily condemn an area to a particular fate. As technologies, knowledge and human resources improve, so does the ability to tackle threats in areas that had previously been judged unrecoverable.

Thus the probability of a biodiversity asset, representative landscape or otherwise, being viable into the future depends not only on biophysical threats, but also on technical and socio-political matters that are not clearly elucidated by threat analyses alone. These two aspects are dealt with in the next two sections.

Knowledge and technical capacity to manage threats

Both this and the next topic represent different aspects of capacity to manage threats. To assess the knowledge and technical capacity to manage threats to a specific biodiversity asset, one needs to ask the question: Are our knowledge and current technologies adequate to manage the existing threats to the biodiversity assets in question? If the answer to this question is no, then the next question becomes: Are the appropriate technologies and knowledge likely to be developed before the biodiversity asset is degraded? If the answer to this question is also no, then the particular biodiversity asset should be accorded a low priority at the time the question is being asked. Given the rapid pace of technological and knowledge development, it may well be that this priority will change within short (less than five year) timeframes. This emphasises the need to continually review priorities.

Where suitable knowledge and technologies do not exist, and the assets threatened are of very high value, then there is a strong case for appropriate research and development.

For those assets where there is a technical capacity to manage threats, then the next question becomes important in terms of the potential for management success.

Socio-political capacity to manage threats

Even if there is the knowledge and technical capacity to manage threats to a specific biodiversity asset, socio-political factors may be a significant barrier to implementing effective management. This is particularly important in agricultural landscapes where, in many cases, support from local farming communities is a critical factor in controlling threats. In these cases, unless there is sufficient support from local farmers, there may be little point in pursuing intensive operational management for biodiversity. Or where a very high biodiversity asset is involved, the initial challenges for managers are social and cultural, rather than operational.

Other key, socio-political factors that significantly affect the capacity to manage threats include broad community and political support for the necessary level of expenditure, and the availability of human resources to implement management action. Of these the first is straightforward. If there is neither political nor broad community support for a particular management project or projects, then they will rarely proceed. However, there will be exceptions in biodiversity conservation where private or institutional groups support projects. Also, while political and broad community support is generally in accord, there are also occasions when governments undertake conservation actions that are not popular. Land clearing controls in South Australia is an example of this (Chatterton and Chatterton 1986).

A key factor that is often not taken into consideration is that, even if funds are made available for a key project or projects, there may not be sufficient suitably qualified people prepared to work in the region. Senior managers based away from key population centres, in the authors' experience, have considerable difficulty attracting and keeping professional personnel in competition with large, coastal cities and towns (see also comments in the concluding chapter in Wallace 2001 as well as the sections dealing with problems/difficulties on pages 43-4 and page 70).

To date methods used by the Department to assess socio-political capacity have largely involved wide consultation with stakeholders, including politicians. It would be helpful if more quantifiable measures of success could be developed.

Conclusions

In this section we have examined priority setting in the context of one type of biodiversity asset, representative landscapes. Effectively this involves selecting landscapes that meet the aspirational goal and which:

1. contain biodiversity assets (in this case a representative living assemblage) that have high value;
2. will, with management, be viable over the life of the goal for the asset;
3. can be managed with existing knowledge and technical capacity throughout the project life time; and
4. have sufficient socio-political capacity for threats to be managed in the life of the project.

To date wheatbelt staff have integrated (1) to (4) in qualitative rather then quantitative ways, however, current work will provide a more robust basis for decision-making in this area. For example, Table 3 below outlines the criteria currently used to select natural diversity recovery catchments in the south-west. Natural diversity recovery catchments are landscapes that contain high value natural, biological and physical diversity assets threatened by salinity. Because of their values, they have been selected for intensive management with the aim of protecting and recovering their biodiversity assets (see Wallace 2001 for more details).

While the detail will change depending on the biodiversity asset involved, the process outlined here applies equally whatever class of asset is being judged.

Table 3: Criteria for selecting natural diversity recovery catchments

Criterion	Comment
Biodiversity values at risk	This is the primary criterion for selecting recovery catchments for natural diversity. Recovery catchments will contain very high nature conservation values at risk. Assessment of catchments will involve the following attributes: • how representative the catchment biota is of important natural communities; • presence of threatened communities and species; • species and community richness; • whether the catchment provides an important biological corridor (e.g. that connecting Lake Magenta Nature Reserve and Fitzgerald River National Park), or other significant ecological service; and • international or national significance of the area (e.g. Ramsar Convention, Directory of Important Wetlands in Australia).
Biogeographic representation	It is desirable to have recovery catchments that represent a range of situations. For example, as many IBRA regions as practicable will be represented, consistent with other criteria.
Opportunities for R&D or demonstration sites	R&D or demonstration sites, particularly those with State, national or international significance, might include special management techniques for: • nature conservation; • farm economics; • cultural change or improved social interaction; and • landcare.
Tenure of land at risk	While conservation lands that are the focus of recovery catchments for natural diversity should be vested with the NPNCA [now the Conservation Commission of Western Australia], other land tenures may be considered for selection as recovery catchments if they are sufficiently important for nature conservation and threatened by salinity.
Representation of hazard	The greater the hazard to an important site, the greater the urgency for action. However, recovery catchments will be selected that represent a range of hazard situations including those that are threatened in the longer term by salinity, but are at present in good condition.
Potential for success	In the main, catchments will be selected that are likely to lead to success. This will involve, for example, taking into consideration: • 'physics' of pressure (e.g. is hydrological pressure overwhelming?); • area of catchment (bigger catchments are generally more difficult to recover); • degree of threat; • level of landcare community support, knowledge and enthusiasm; • potential to use prospective commercial species in revegetation; and • current area and distribution of remnant vegetation (the more the better).
Socio-political considerations	There will be demands from a wide range of socio-political stakeholder groups ranging from catchment groups to federal agencies and politicians. The demands from these groups will need to be taken into consideration.

Priority management strategies

Once a project to protect a particular biodiversity asset has been selected, the next task of operational management is to analyse the types of management strategies that need to be implemented, and to rank them.

Developing and ranking management strategies involves two major types of decisions. Firstly, there is the question as to which threats are most likely to prevent goal achievement. Secondly, there are questions concerning the capacity and ability to implement management strategies. These questions may be re-written as: What are the most important and urgent threats to tackle? And do we have the technical and resource capacity to implement management? Not surprisingly, the process used for deciding priority strategies at the project scale echoes that described above for selecting priority sites for management.

Once a goal has been established for a particular management project, the threats to achieving that goal may be developed within the threat structure described above. When the list of threats has been established, then their relative importance may be calculated by assessing the probability that they will prevent goal achievement, often expressed as the probability of causing extinction of one or more wildlife populations within the target area. If there are unmanageable threats with a probability for preventing goal achievement of 1.0, then the goal needs to be changed to something that is achievable. (If resources permit, research or other steps to tackle the most serious threats would also be appropriate.)

Those threats that represent the greatest risk to goal achievement need to be managed as a matter of priority, although normally a range of threats is managed concomitantly. Note also that threats that are currently low priority – for example, a small infestation of an aggressive weed – may be of higher priority given their longer-term implications. For this reason threats should generally be considered over time scales of at least 50 years. An example of this process is described above (see Table 2) for the Dongolocking area.

To date, testing of this threat ranking process has only begun in the Region. However, it is intended to develop the method further and use it much more widely as a means of ranking management strategies for a range of assets. For example, Appendix 5 describes the current range of management strategies being applied to counter particular threats and achieve project goals for a range of biodiversity assets. Note that, whether the asset is a population, a representative landscape or the biota of an individual remnant of natural habitat, the same range of management activities applies. Currently, Regional budgeting is undertaken at each of these scales, and this enables statistics to be collated for any one scale or across scales for a particular management activity.

However, it is not enough to identify the most important threats to tackle. It is also important to consider the probability of success if a particular threat is managed. There is little point implementing management strategies for which there is a high probability of failure. Similarly, there is little point in tackling one threat, such as weed invasion, in an area significantly threatened by salinity unless the latter is manageable. In this regard the next step in the wheatbelt is to explore ways of accounting for the synergies and antagonisms among threats within a specific project area.

Management strategies should be regularly reviewed given that allocation of significant new human resources, or the advent of technical innovations, may change the probability of success for particular management strategies and lead to a re-casting of strategic priorities. This underlines the importance of constantly reviewing goals, achievements, available management strategies and priorities.

Thus the process for establishing strategic priorities for action within particular projects is very similar to that used for establishing priorities among a group of similar biodiversity assets. While the methods described here need considerable further development, they provide a useful framework for operational management for biodiversity conservation.

Project goals

Throughout the above discussion, broad, aspirational goals have been viewed as the fundamental driver of the management process. A goal is the constant reference point, particularly for defining and ranking biodiversity assets and evaluating the importance of threats. Ultimately, goals also provide the reference point for monitoring and evaluation and evolving management actions. However, as may have been noted with the Dongolocking example, a much more specific goal than the aspirational goal is needed to drive analyses at the project level. While it is not practicable in a document such as this to define specific project goals for the whole Wheatbelt Region – these will differ depending on the asset being managed and the circumstances – it is useful to explore the types of goals that will be meaningful for a range of projects.

The foregoing discussion provides a basis for elaborating project goals that integrate elements of the six, broad management strategies discussed in the section above on 'Values, vision and goals' with spatial and time scales. Additionally, in the Wheatbelt Region the two most significant environmental threats driving development of project goals are salinity and the lack of habitat remaining (that is, lack of ecological resources). Based on the opinion of experienced Department managers, these two threats have a probability of 1.0 of causing regional extinctions within the next 50 years given current levels of management. Therefore, they are used here to structure project goals further in the case of the Wheatbelt Region.

For many areas it is not feasible to prevent the expansion of salinity, and loss of some biodiversity from many sites is inevitable. In the case of fragmented habitats, there is some evidence (see, for example, Andrén 1994 and Reid 2000) that, where between 20 to 50 per cent of the original habitats remain at a landscape scale, then most native biota will persist. Several studies have examined the effects of forest cover within landscapes of varying size on bird species richness (for example, Bennett and Ford 1997, Reid 2000, and Cooper and Walters 2002). Based on these studies, we defined a viable landscape as being in the order of 30,000 hectares with six to 15,000 hectares of original habitat remaining. See Appendix 3 for a more extensive discussion of this topic. Using this as a crude guide as to what is required in the wheatbelt, and combining it with salinity threat and the scale and other issues previously discussed, the project goals outlined in Table 4 (adapted from Wallace 2003) were generated. The work of Main (1987) provided an important stimulus for developing this table.

Thus the aspirational goal for conserving biodiversity, that is: *to protect, conserve and, where necessary and possible, restore, Western Australia's natural biodiversity*, is applied in the Wheatbelt Region as a variety of situation-specific, project goals that range from slowing the rate of biodiversity decline to restoring elements of the regional biota. These project goals, as outlined in Table 4, drive conservation management in the Wheatbelt Region. The options outlined in the table provide a valuable framework within which to develop more specific project goals.

For individual projects, these goals are developed into specific project goals by adding more precise definitions of the biodiversity assets to be managed, plus the spatial and time scales over which management is to be undertaken[11]. For example, the following represent a range of specific project goals used within the region:

1. conserve all populations of the threatened species *Acacia depressa* over the next 10 years [12];
2. conserve the brackish-freshwater community at Toolibin Lake in perpetuity;
3. conserve the native biota within the Dongolocking Study Area for 50 years.

These types of goals are measurable, time bound and refer to a specified biodiversity asset, or assets, at a particular location. However, note that the area treated by management may need to be larger than the area specified in the goal. For example, in the case of (2) above, the catchment is managed to conserve the brackish-freshwater community at Toolibin Lake. These types of goals lend themselves much more readily to monitoring and the application of performance measures than do the more generalised goals that are often necessary at corporate and regional levels.

Having considered goals and priority setting, monitoring and performance measures are the final issues that need to be considered to complete the framework.

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[11] In operational management, this effectively defines a project as work to manage specific biodiversity assets over specific time and spatial scales to achieve a particular goal. In a broader corporate sense, there are many other types of projects that will be implemented to achieve the Department's aspirational goal (e.g. projects that aim to recruit and train personnel to be effective operational managers etc.).

[12] The time scale of management plans is an interesting issue. Ten years is commonly set as the period for a management plan written for land managed by the Department. At Dongolocking, 50 years was used because the authors considered it the longest timeframe over which they could conceptualise management. In perpetuity is effectively expressing an aspiration that a goal will be achieved 'for the foreseeable future'. Given the dynamic nature of ecosystems, this is not a particularly useful way to express a goal, and ignores the concept of allowing systems to naturally evolve.

Table 4: Project goals in the context of the aspirational goal. (Table adapted from Wallace 2003)

Landscape salinity risk	Management unit type	Regional biodiversity conservation goal
Management area lies within landscape units at very low risk from salinity.	Large (>10,000 hectares) conservation reserves and adjoining lands (landscape).	To conserve all existing taxa of native species in their natural or near natural habitats.*
	Large (>30,000 hectares) managed landscapes of which a minimum of 25 to 30 per cent or 6,000 to 10,000 hectares of natural or semi-natural habitat exists and operates as a non-fragmented unit. Management of threatened communities often occurs within this category.	To conserve all existing taxa of native species (or threatened community) in their natural or near natural habitats.*
	Managed populations of threatened species.	To conserve the threatened species, or if this is not practicable, then manage the genetic material of the species to maintain it in perpetuity by translocation or *ex situ* preservation.*
	All other areas. Operational management often at level of small area of natural, remnant habitat.	To prevent or minimise the introduction of new threats and to slow the rate of decline.
Management area lies within a landscape, or includes landscape units, highly threatened by salinity.	Catchment (landscape) that includes significant threatened community(ies) or species that it is feasible to manage so as to protect from the worst effects of salinity.	To conserve the threatened community(ies) or species.*
	All other areas. Operational management often directed at small areas of natural, remnant habitat.	To prevent or minimise the introduction of new threats and to slow the rate of decline; and/or Identify unique taxonomic elements that will be lost and arrange translocations or conserve representative sample of genotypes *ex situ*.*

* In each case where a goal begins "to conserve…." it should, where applied to a specific case, also include a statement as to the timescale over which the goal is to be applied and the probability of success.

Monitoring, performance measures and outcomes

After working through the earlier components of the framework, it is clear that monitoring and performance measures should centre on the status of biodiversity assets that are important to achieve the aspirational goal. The most important question will be: Are the biodiversity assets necessary for achieving the aspirational goal adequately conserved, protected and (where possible) being recovered? Following earlier discussion, this question can be asked at a range of spatial and temporal scales, and in some cases may be applied at a scale as small as one population of one species. These types of measures are also outcome measures, and reflect the effectiveness of management in delivering the aspirational or project level goals. Note also that, given the constraints on achieving the aspirational goal dealt with at the beginning of this document, management outcomes will sometimes be considered sufficient if they slow the loss of biodiversity at a particular locality, or conserve threatened germplasm in an artificial storage system.

Although outcome monitoring against goals (including appropriate temporal and spatial scales) is the pre-eminent monitoring task, it is also important to measure management efficiency. Efficiency is considered here to be a relative measure that assesses whether the implementation of strategies and technologies has been at minimum resource costs in comparison with alternative strategies and technologies. In this regard, the performance (output) measures shown in Appendix 5, when matched with expenditure, provide a firm basis for comparing the efficiency of alternative strategies and technologies.

One final, general point should be made concerning monitoring. This is that monitoring should be consistent with the principles of adaptive management (Holling 1978). There is much that we do not know about managing natural environments, particularly the highly variable, uncertain environments of the wheatbelt. Therefore, apart from the most straightforward management projects, management operations are effectively experiments. This needs to be recognised through the explicit documentation of management objectives, the assumptions that underlie them and the selected management actions. In turn, these must be combined with effective monitoring and evaluation of outcomes. The framework developed in this document – which emphasises rigorous goal setting in the context of alternative broad options, and transparency of priority setting including threat analyses with documented assumptions – lends itself to use in adaptive management. In this regard effective monitoring and evaluation are essential to close the management circle (see Figure 2) so that goals are adjusted and management strategies adapted in line with experience.

For the remainder of this section, the focus is on the levels at which monitoring and performance could be measured in relation to outcomes, with some further comment on efficiency methods. The most obvious levels for monitoring are one or more of State (or corporate), regional (including district) and project levels. Appropriately structured, monitoring at the project level may be accumulated at any spatial scale to provide a measure of how well the aspirational goal is being achieved. Therefore, the two key levels for monitoring are the project level and corporate level, with measures at regional and district levels reflecting the corporate level, but over smaller areas.

Performance at the project level

To date, performance measures used within the Wheatbelt Region have mainly dealt with lower level product outputs linked to expenditure and management strategies directed at specific threats (see Appendix 5). These data are recorded against either particular projects – such as a specific landscape scale project – or a general 'slowing the rate of habitat decline' goal. A similar system was used to produce the Department's Salinity Review (Wallace 2001). Although this process does generate useful information that allows comparisons between projects, including costs per unit of production, it does not generate the more outcome related data required to assess goal achievement properly.

Therefore, goal development in line with the structure shown in Table 4 will be increased over the coming years to ensure management projects are better monitored and their effectiveness in achieving outcomes assessed. Some examples are provided below with respect to each of the key management scales at which regional officers operate. In preparing this section, we have drawn heavily on work undertaken by a project group of the Avon Catchment Council (Wallace *et al.* 2002).

Populations/species

Most work at this scale involves management of threatened species. Currently, critically endangered species are the focus of management activity, and this work is generally undertaken under the umbrella of a particular management plan, recovery plan, or interim management guideline. These documents should be referred to for details on monitoring, etc. However, an example for the woylie (*Bettongia penicillata ogilbyi*) is summarised in Appendix 6 based on data prepared by Start *et al.* (1995) and Start and Burbidge (1996).

In some cases operational management is aimed at counteracting a key threatening process in relation to a number of threatened species. For example, the introduced fox is a key threat to many native species of mammals, and there are currently generic fox control programs that aim to protect a range of species from the fox (Department of Conservation and Land Management 2001a). Monitoring in these projects usually uses an indicator species – a native species (not necessarily the main target of control methods) that is known to be highly susceptible to fox predation.

Threatened communities

In the Wheatbelt Region, formally recognised threatened communities must be managed at landscape scales. This is dealt with in the section below on that scale.

Protection of natural habitats

Unless undertaken with regard to a particular species or landscape, work at this scale is generally focused on slowing the rate of biodiversity decline. In a monitoring sense, this would require the capacity to detect a change of trajectory in some variable(s) from what it would be under a 'do nothing' scenario. To date, no cost-effective mechanism has been developed for monitoring outcomes at this scale of endeavour. However, Wallace *et al.* (2002) proposed Table 5 as an outline of the types of targets and strategies that might be adopted by the Avon Catchment Council. Note that the strategies and targets listed in the table are examples to indicate a possible approach – the table is not intended to be at all comprehensive.

Other important strategies, particularly those related to not accelerating the rate of decline, such as the implementation of land clearing controls and the prevention of new exotic introductions, are comparatively easy to monitor.

Landscapes

Most work undertaken at this scale occurs in the context of a management plan or guideline. Work at this scale often involves a threatened community, for example, the management of Toolibin Lake to recover it from salinity. This work is covered by a particular recovery plan (Toolibin Lake Recovery Team and Technical Advisory Group 1994). These plans generally establish outcomes and criteria for measuring them. A summary of the criteria and an assessment against them for the management of Toolibin Lake is shown in Table 6.

Table 5: Examples of targets and strategies for slowing the rate of biodiversity decline

Strategy (with the addition of spatial and temporal scales, these become projects)	Examples of targets
Improve the security of tenure of remnant habitats. (Note that improving security of tenure usually involves a component of direct management, but other issues make it a useful separate category, at least initially.)	Increase the amount of remnant habitat in Class 'A' nature reserves to x hectares by 200Z. Increase the amount of remnant habitat on private property covered by conservation covenants to x hectares by 200Z.
Improve the management of remnant habitats.	Within private property, increase the area of remnant habitat protected from domestic stock by x hectares by 200Z. A 30 per cent increase in the amount of native vegetation with implemented fire management plans. Buffer x hectares of remnant habitats from pesticide drift by 200Z.
Enhance the quality of remnant habitats.	Create additional habitat by revegetating x hectares per year for five years. Protect x hectares of remnant habitat in wetlands from salinity by 200Z.

Table 6: Toolibin Lake – Progress Against Recovery Criteria (Taken from Wallace 2001, page 63)

Recovery criterion	Current progress (1997-2000)
Biological criteria No further deterioration is observed in the health of the vegetation of the lake or the reserves.	Further deterioration has occurred over much of the lake vegetation, less so within the reserves. However, there are also areas on the lake floor where the vegetation has improved in condition, and this improvement is considered to be due to recovery activities.
Successful tree and shrub regeneration in the lake and reserves is established in all vegetation associations.	There has been extensive seedling establishment over several hectares of the lake floor.
Based upon available data, the lake supports sufficient species richness and numbers of invertebrates to assure waterbird food resources.	The lake has not filled or partially filled since 1996. Based on data at that time[13], this criterion is considered to have been met.
The numbers and species of waterbird visitation (41 species) and breeding success (24 species) that currently occurs is maintained or improved.	The lake has not filled or partially filled since 1996. Based on data at that time, and the ability to control in-flow salinity, this criterion is considered to have been met.
Physical criteria The minimum depth to the water table beneath the lake and Toolibin Flats in spring, when the lake is dry, should be 1.5 metres.	In general terms the water table has been stable or dropping near groundwater pumps, and slowly rising or stable away from groundwater pumps.
The maximum salinity of lake water when the lake is full should be 1,000 mg/litre Total Dissolved Salts (TDS).	While the lake has not filled since 1996, the construction of the diversion channel and separator gate has enabled managers to divert water around the lake that does not meet this criterion. Therefore, the criterion has been met.
The maximum salinity of inflow to the lake, measured at the Water Authority gauging station 609 009 on the Northern Arthur River, should be 1,000 mg/litre TDS during the winter months when the lake is full.	Criterion met by creation of diversion and separator gates.
The lake bed dries periodically by evaporation, on average once every three years.	Lake has been dry during period. Criterion needs to be reviewed.
The levels of nutrients within the lake should not cause excessive growths of algae or other aquatic plants, or cause deleterious reductions in dissolved oxygen concentration in the water. Total phosphorus levels in the water should not exceed 100mg/litre unless long-term monitoring indicates that this criterion may be modified.	No lake filling during the period. However, by-passing of early flows may assist in meeting this criterion.

[13] Note that this conclusion is reached by comparing the data from 1996 (that is, at that time) with a considerable amount of data collected previously. The language of the original table – used unchanged here – is ambiguous.

Note that, for Toolibin, the recovery criteria have been established so that, if they are met, then the goal (outcome) of: ensuring "the long-term maintenance of Toolibin Lake and its environs as a healthy and resilient freshwater ecosystem suitable for the continued visitation and breeding success by the presently high numbers and species of waterbirds" will be met.

General comments on monitoring at the project level

From the above examples, two types of performance measures in relation to biodiversity assets become apparent. Firstly, there are those related directly to the status of a specific biodiversity asset or group of assets. For example, some of the biological recovery criteria used at Toolibin and many criteria used for threatened species fall into this category.

Secondly, there are performance measures that evaluate the effectiveness of operational management in relation to management of particular threatening processes. The instance above concerning fox control is an obvious example, and land clearing controls and work to prevent the introduction of invasive exotic species are others. In most cases such projects will still be evaluated in relation to particular biodiversity assets, but sometimes monitoring will focus on process measures. For example, in the case of Toolibin, the physical criteria used reflect how well hydrological and other processes are being managed. (Although at Toolibin there are also direct measures of biodiversity asset status.)

Both types of measures are valuable. However, wherever practicable, they should be linked back to the status of one or more biodiversity assets.

Performance and the aspirational goal

At the broadest level, it is important to monitor and evaluate achievements in relation to the aspirational goal. Following from the previous section, this may be achieved by either assessing the status of biodiversity assets, or by evaluating the management of a threatening process.

Given the aspirational goal, performance could be measured in terms of extinction rates (loss of biodiversity assets) at an appropriate scale, a measure calculated from project level data. Under this scenario, the more effective management is, the slower will be the rate of extinction. In practical terms this form of monitoring is difficult given the long time frames – in comparison with budget cycles – over which data must be collected before significant trends can be observed. Even then, ascribing cause and effect within such broad trends is very difficult.

Alternative approaches are to evaluate management against more short-term outcomes. For example, the Department of Conservation and Land Management (2001b) uses performance indicators in relation to three areas: wildlife habitat management, wildlife utilisation, and threatened species management. Measures include indicators such as:

- "Population estimates for native fauna susceptible to fox predation in areas where fox baiting is occurring, as shown by monitoring sites in each CALM region where *Western Shield* is operating"; and
- "The number of the State's wildlife taxa identified and listed as either threatened or requiring special conservation attention, compared to previous years".

At the process (threat) level, one could assess rates of habitat loss, or rates of exotic introductions, land surface area affected by salinity, and so on.

Given that the biodiversity conservation goal for the Wheatbelt Region is identical with that at the corporate level, it as at the latter scale that the relevant monitoring and performance measures will be determined, and the issues are not discussed further here. However, it is apparent from discussion in this document that there are a range of issues that need to be worked through in order to ensure that human values, the corporate goal, and management actions are all effectively connected and evaluated through monitoring programs. The ability to achieve this will depend on how well management processes identified earlier in this document are implemented.

Conclusions

To date simple monitoring and evaluation mechanisms have been used in the Wheatbelt Region. It is proposed to improve monitoring and evaluation systems further, particularly with regard to goal development, better documentation of the performance measures shown in Appendix 5, more widespread use of performance criteria such as those found in recovery plans, and the integration of these elements with expenditure to provide an effective monitoring and evaluation tool.

Finally, for reporting at regional level, it is proposed to develop further the recent work on IBRA regions undertaken during 2002 by departmental officers (National Land and Water Resource Audit 2002).

Concluding remarks

This document has outlined an approach to managing natural biodiversity in the wheatbelt of Western Australia. It is important to emphasise, as stated in the introduction, that this document is designed to stimulate discussion and debate, and it has been written in the expectation that the methods described will enjoy considerable improvement in the coming decade.

While the document has explained the framework in the context of an agricultural environment, the processes described are equally applicable to those pursuing similar aspirational goals in all other environments. The key differences will relate to the types and viability of biodiversity assets, and to the sorts of threats that are pre-eminent. The latter will affect, in particular, the management strategies that need to be developed and implemented.

Throughout the document, areas of weakness in the framework have been noted. These are summarised below in relation to the key components of the framework:

1. *A description of the key elements of the wheatbelt environment*, including the cycles that drive component interactions. An account of these is provided in Appendix 1, and was referred to at the outset as setting a broad context for the framework rather than being one of its key components. However, this context is very important, and could be significantly improved by a more academic re-working, and further testing in practical situations.

2. *An aspirational goal and management goals that effectively guide operational management*. The importance of these cannot be overstressed. A key weakness of much conservation planning is the failure to develop appropriate and effective goals. While the discussion of broad management strategies has helped goal development and has withstood testing over the past four years, the description and use of human values or needs in driving goals has not been well developed. There is an urgent need to develop our understanding of human drivers and their connection to goals, including aspirational goals. This would also provide greatly improved opportunities to connect peoples' lives with the importance of biodiversity conservation.

3. *A description of the biodiversity assets that must be conserved to achieve the aspirational goal*. This component of the framework needs considerable development, both in terms of definition and in relation to ensuring that there are clear connections between assets, goals and human values. If these three elements are not satisfactorily connected, there will be a damaging miss-match that will probably result in poor outcomes that do not satisfy human aspirations.

4. *A description of threats to goal achievement, and a process for using them to rank management strategies and identify priority sites for action*. The structure, definition and use of threats to analyse and develop management priorities have proved useful in their limited applications to date. There are obvious needs to test and develop all aspects of the use of threat analysis. This includes the importance of testing, in a more academic sense, the ideas and definitions used.

5. *Monitoring and evaluation methods that effectively link goals, on-ground outputs and outcomes*. In the experience of the authors, this component of management is generally poorly done across southern Australia. There are many practical reasons for this, including the difficulty of maintaining monitoring over long time periods, the failure to commit adequate resources, and the lack of rewards for a process that is demanding and inclined to highlight failures, rather than successes. While these three issues reflect institutional and individual human characteristics, the failure to develop and link components (1) to (4) effectively has also caused significant problems. Unless the four preceding components are effectively developed and linked, it is difficult to generate useful monitoring and evaluation techniques.

In closing, the authors have found the process of thinking through the issues in this document challenging and rewarding. Through constant testing of the ideas in practical application and discussions with colleagues, our ideas have evolved, and continue to evolve. The framework in its current form has helped us to improve all aspects of our management, including better linking the day-to-day work of officers with the critical issues – or threats – that need to be managed. We look forward to the framework continuing to evolve and assisting managers to implement effective operational management.

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Appendix 1: An ecosystem outline for agricultural environments.

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Introduction

During 1997-99 six pilot projects for planning remnant native vegetation management were undertaken throughout Australia under a national initiative. The objective of these was to develop methods for planning sustainable native vegetation management in rural environments at a regional or catchment scale. One of these pilot projects – the Dongolocking case study – was based around a group of nature reserves and other remnant vegetation in the wheatbelt of south-western Australia (Wallace 1998*a*).

During development of this project a number of general texts on ecology were examined. While these texts adequately describe ecosystems and associated biogeochemical cycles and fluxes, none that clearly list the key biotic and abiotic elements of ecosystems were found. Nor did any link biogeochemical fluxes and cycles with the concept of threats (see Appendix 4 for a description of threats). Thus the fundamental elements of agricultural environments, the processes that connect them and their expression through threats are assumed.

To plan and implement on-ground management in any holistic way, it is important to take into consideration these elements and the processes that describe their dynamic relationships. In this Appendix we briefly outline the key elements of agricultural ecosystems, the fluxes that describe their interaction, and how these link to the expression of threats. Such an approach encourages managers to plan their work with an understanding of ecosystem elements and function, and maximises their ability to develop adaptive management strategies. This account is based on that in Wallace (1998d).

Describing environmental elements and their interaction

Planning of civil works (such as roads) and production systems (for example, a new cereal crop) in rural areas generally involves a narrow planning view of the rural environment. This reflects the broad community acceptance of these activities as central to rural life. Consequently, there is little pressure in planning these activities to consider the full range of environmental elements in agricultural districts. This narrow view of planning production systems has often resulted in extensive changes to ecosystem processes with consequent losses to biodiversity and other degrading changes to rural ecosystems.

However, to plan the conservation of any natural resource requires a much more comprehensive analysis of the rural environment. This is for two reasons. Firstly, most rural activities impinge on natural resources and therefore complex issues and interactions are involved; and secondly, conservation of these resources is not widely accepted as of central importance among rural communities.

Therefore, in planning for conservation of natural resources in agricultural environments it is essential to identify the key elements and understand how they interact. Environmental elements that must be integrated in planning are outlined in Figure 4. In this figure, the separation of the agricultural environment into living and non-living components and their various elements is, broadly, a 'text-book' approach except for two important features.

Firstly, cultural structures – such as roads, railways, buildings, fences, etc. – are important abiotic components of rural landscapes. These are particularly important in agricultural environments as they have significant effects on the movement of living and non-living elements. For example, roads may be barriers to animal movement, or conversely, act as corridors for movement where there are significant amounts of roadside vegetation. Similarly, roads and other structures may affect water flows in ways that detrimentally affect the environment.

Secondly, biotic components in Figure 4 are separated into human needs and non-human elements. This division emphasises that the agricultural landscape is largely a cultural one. In this context the expression of human needs will have a profound impact on the wider environment, and their explicit consideration will be fundamental to successful management.

In the Dongolocking case study, which stimulated the development of this outline, human needs are expressed through four major demands on the project area:

- economic needs, particularly as expressed through agriculture;
- nature conservation aims, which are largely an expression of the desires of the community outside the Dongolocking area, although they are also stated by those living within the study area in various forms (Bone 1998);
- recreation demands, reflecting the desires of some people both inside and outside the project area; and
- aesthetic demands, which also reflect the desires of some people both inside and outside the project area.

Although in the case of Dongolocking and many other wheatbelt landscapes it is convenient to use these readily identified demands as the human drivers for planning, they in turn reflect more fundamental human needs (for example, Forman 1997) that are usually some variation of the list in Figure 4. Discussion of these in greater detail is contained in Appendix 2. However, while their importance and implications for land management are profound, they are generally not well understood.

Ultimately, local management of natural resources will almost certainly fail if it does not meet the human needs of the most powerful stakeholders. A complicating feature for landscape planning and management is that it should take into consideration the impacts on other landscapes and other external stakeholders. In the Dongolocking case study this included, for example, downstream landholders concerned that they will receive excess water or salt from upstream, and conservation groups seeking protection of key areas from their perspective. Additionally, in fragmented environments the high level of boundary interaction heightens tensions between land uses.

The remainder of the elements in Figure 4 are widely recognised and require no further explanation.

Interaction of elements and the use of threat analysis

As shown in Figure 4, interactions between environmental elements, including dynamic and temporal aspects, are described through environmental processes such as water, energy, nutrient and oxygen fluxes. The importance and operation of some of these environmental processes are described for the Western Australian wheatbelt in the work of Main (1993), Lefroy *et al.* (1993) and other papers in Hobbs and Saunders (1993).

Vegetation in agricultural areas of southern Australia has been fragmented relatively recently, and the consequences of significantly disrupting environmental processes are still being played out. For example, disruption of the hydrological cycle by replacement of perennial native vegetation with annual cereal crops is having profound effects on surface soil salinity. In parts of the south-west, these effects will take over 200 years to be fully expressed (Agriculture Western Australia *et al.* 1996). This emphasises the importance of understanding environmental processes and the changes wrought by modified land use.

The question now arises as to how land managers and planners can best account for environmental processes in planning for fragmented landscapes. This issue is acute given the poor understanding of processes and the complexity of their interaction. Current disagreements concerning the relationship between the carbon cycle and global warming are a reminder of how little we actually know and the uncertainties we face.

Various combinations of risk management, threat analysis and probability have been used, or are proposed for use, in natural resource management (for example, Burgman and Lindenmayer 1998, Main 1992a, The Nature Conservancy 2000a, Young and Millar 1997). In the work at Dongolocking it was decided that a similar approach would also provide the most effective method of accounting for perturbations in environmental processes that threaten the achievement of land use goals.

Where the functioning of an environmental process endangers a land use goal, this may be described as a threat to that land use goal. For example, threats to a range of land use goals posed by increasing surface soil salinity and waterlogging result from perturbations in the hydrological cycle, and predation of native fauna by the introduced fox (*Vulpes vulpes*) signals significant changes in nutrient and energy cycles. Documenting existing and potential threats along with management responses is one means of accounting for environmental processes when planning management.

A key issue not resolved here is whether all threats to biodiversity generated by humans should be considered, as in this document, as mediated through other, more fundamental environmental processes or fluxes. An alternative approach is to view socio-cultural activities themselves as fundamental environmental processes.

In summary, the elements of rural environments and their interaction through processes have been described above. Interaction of environmental components through processes is well understood in principle, but less so in practice. Evaluating threats to particular land use goals provides a useful method for assessing where the functioning of environmental processes requires management intervention.

Figure 4: Planning components in an agricultural environment.

Agricultural environment

Abiotic components

Air, e.g.
- atmosphere
- soil air

Water, e.g.
- surface water
- groundwater
- soil water

Geomorphology, etc.,
- soils
- parent rock
- landform

Energy, e.g.
- sunlight
- organic compounds

Cultural Structures, e.g.
- roads
- buildings

Biotic components

Non-human components, e.g.
- introduced and native plants
- introduced and native animals
- micro-organisms

Humans and their needs, e.g.
- food, water and oxygen
- energy
- shelter
- minimal physical threats
- companionship
- successful reproduction
- spiritual/philosophical well-being
- physical and mental health
- meaningful occupation
- some level of luxuries.

Interactions between the above components, including spatial and temporal aspects, are described through environmental fluxes and processes. Of particular relevance in agricultural environments are water flux, nutrient fluxes, energy flux and oxygen flux. Other processes are 'sub-processes' of these fluxes. For example, predation is part of nutrient and energy fluxes, erosion part of energy and water, climate part of energy and water, and so on.

Appendix 2: Biodiversity conservation and human needs.

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The Department's corporate goal (or objective) for biodiversity conservation is:

> *To protect, conserve and, where necessary and possible, restore Western Australia's natural biodiversity.*

To understand the importance of this goal, it must be explicitly tied to human values. However, most people have little understanding of the linkages between human values and biodiversity conservation. Therefore, it is important to clarify these linkages and to underline the importance of conserving natural biodiversity to humans. Generally, the value of conserving natural biodiversity is expressed in terms[14] of:

a. *Consumptive use values*: these include the values of natural products that are harvested for domestic use and do not pass through a market. The most important consumptive uses of biodiversity by humans in the wheatbelt are as food (for example, kangaroos), energy (firewood) and building materials (for example, farmer use of on-farm native timbers for fencing and other light construction). While Noongars and early settlers used native plants and animals as medicines, they are rarely so used today. Note that increased harvest of native eucalyptus and melaleuca oils may change this situation.

b. *Productive use values*: are the values of natural products that are commercially harvested. Examples in the wheatbelt include kangaroos for hides and pet meat, wildflower harvesting, firewood cutting, and building materials. Sandalwood and other products from woody plants are also increasing in importance.

c. *Opportunity values*: in contrast with all the other values listed, this category includes values that have not yet been realised. The most obvious opportunity value in the wheatbelt is the potential to develop new industries based on the region's rich natural biodiversity, particularly the flora, which is of international significance. Given the socio-economic importance of developing new sustainable industries in agricultural areas, the diversity of the South-western flora, and increasing use of genetic engineering, it is vital that Western Australians protect the opportunity value represented in the wheatbelt's unique genetic resources. However, there are other opportunity values represented in the wheatbelt's natural biodiversity. For example, the range of tourism and recreation opportunities represented in the region's natural lands that may be developed as the State's population grows.

d. *Ecosystem service values*: are those values of natural diversity that contribute to the maintenance of our environment, particularly the processes that ensure that human life can persist. Across all scales, this includes the production of oxygen by plants, and the fixing of carbon by plants and other organisms. At the scale of the wheatbelt, the role of wetlands in flood mitigation and nutrient stripping, and the function of remnants of native vegetation in helping to maintain water use are examples of ecosystem service values. Local scale examples of ecosystem service values include remnant native vegetation growing on highly erodible surfaces, and the contribution of native animals to pest control.

e. *Amenity values (including aesthetic values)*: Amenity is defined by the Macquarie Dictionary as the "features, facilities, or services of a house, estate, district, etc., which make for a comfortable and pleasant life". Amenity values of natural diversity in the wheatbelt include pockets of bushland around houses and yards that provide shade and shelter from wind. Pockets of remnant bushland used for stock shelter could be considered here, but are probably better thought of as productive use. The beauty aspects of natural diversity, including landscape views and specific natural features such as breakaways and granite rocks, are part of amenity values.

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[14] Some of the definitions are based on those in *Conservation Biology for the Australian Environment* by M. A. Burgman and D. B. Lindenmayer, Surrey Beatty & Sons, Chipping Norton, 1998. However, other definitions are not based on Burgman and Lindenmayer, and those they list related to 'intrinsic values' are omitted or incorporated into other categories. For example, altruistic views (for example, the 'right' of all species to exist) are considered to relate more to spiritual and philosophical values, and are therefore included under that category.

f. *Scientific and educational values*: are the values of natural diversity as a source of knowledge and learning. For example, remnants of native vegetation provide the only source of reference material if we wish to assess how agricultural practice has affected soil structure and other properties. Additionally, many institutions use areas of natural lands for educational purposes - they are important if we want to understand our land and how it works. Teachers frequently use natural bushland as an educational resource in this context, but also for broader learning opportunities.

g. *Recreational values*: natural bushland and features, particularly salt lakes and granite outcrops, are widely used in the wheatbelt for recreation and tourism. The positive connection between recreation in natural environments and physical and mental health is well researched and documented. At a farm scale, most children who grew up on farms will remember the patch of bush or granite outcrop that was a special place to play. In some cases these areas remain as a spot for family outings. The strong local ownership of places – often granite outcrops – that have been used for several generations, testifies to the transition beginning for some places from this category (recreation) to the spiritual/philosophical category.

h. *Spiritual/philosophical values*: natural bushland, including the remnants along roadsides and in paddocks, helps to define 'our place'. While rarely articulated, this is an important part of Australian cultural identity, something that helps to define our uniqueness in the world. As noted in (g) above, for some rural people there is increasing emotional attachment to local places, and this signals the beginnings of spiritual connection with the land. In the case of urban people, this emotional connection is likely to be with a regular, cross-generational holiday destination, such as a natural coastal area or a forest. Everyone holds spiritual/philosophical beliefs that connect him or her in one form or another with the natural environment. While often these beliefs are not explicit, sometimes they are strongly held and overt. For example, many people hold strong views that all life has a right to live. Such views are considered here to reflect spiritual or philosophical beliefs.

Conserving natural biodiversity contributes to all the above values (a) to (h). However, in the more restrictive sense of nature conservation, it is generally thought of as primarily contributing to (c), (d), (e), (f) and (h), together with passive recreation (part of (g)).

While the above is a comparatively standard definition of values, it is also useful to consider how biodiversity conservation might be linked to fundamental human needs. This entails re-structuring the categories above to directly reflect basic human needs. One means of doing this is as follows (with the fundamental needs in italics):

Food and water: already our native plants and animals contribute to food resources. While this mainly involves marine resources and kangaroos, bush foods are becoming more popular as their food values are recognised. Some harvesting will be from wild populations as currently occurs with kangaroos and fish; however, in other cases the genetic resources represented in wild stocks will be the key value of natural wildlife.

There are also many indirect connections between biodiversity assets and food and water production. For example, animal husbandry depends on fencing, which is in turn mostly based on south-west timbers (although with the severe decline in local timber resources, steel and other abiotic materials are now supplanting wooden posts). Most preferred fencing timbers are derived from locally native species from a number of genera. Remnants of native vegetation also play an important role in agricultural land conservation, both directly – for example soil erosion and salinity control – and indirectly as a genetic resource. In the case of water production, both private bushland (in catchments for on-farm supplies for stock water and domestic use) and Crown reserves (including those in the catchments of rural town supplies) are important for protecting water resources. There are many other examples of the ecological service values of biodiversity contributing to food and water production.

Finally, given the genetic wealth of the south-west it is vital that we act to conserve our genetic resources in perpetuity. In the agricultural zone, in particular, we can ill-afford to lose any more areas of native bushland. With appropriate research and development, they offer a cornucopia of future products.

Energy: the high value of the firewood and other energy resources provided by our native plants is poorly recognised. With the imminent trial of oil mallees as a source of biomass fuels, the use and importance of our native flora may expand considerably. Experience with the oil mallee project has underlined both the importance of conserving genetic resources and their potential contribution to sustainable energy production.

Shelter: a wide variety of native species are already in use (both as native vegetation remnants and individual plantings) to provide protection from wind and sun in rural areas, particularly around buildings and stock yards.

Again, this use, and the variety of species involved, is set to expand. Historically, a wide range of native timbers were used as building materials, and this use could be developed in conjunction with revegetation for conservation purposes.

Minimise physical threats: the major contribution of biodiversity relates to flood mitigation and nutrient stripping values of wetlands, and the impact of bushland on climate.

Companionship and sense of belonging: bushland is not only the basic resource for social values derived from recreation and tourism on natural lands, it provides an important sense of place that contributes to the identity of individuals and communities.

Successful reproduction: no direct relationship, only through other needs. For example, physical and mental health contribute to successful reproduction.

Spiritual/philosophical well-being: for some groups and many individuals, natural bushland and associated features are an important spiritual resource. This is very rarely discussed or expressed, but comes out in the surprisingly high level of 'ownership' and sensitivity that local people sometimes express in relation to bush areas such as those based on granite outcrops.

Physical and mental health: the connections between recreation in natural lands and physical and mental health are well documented. Note also the potential to utilise products from native vegetation in the development of new medicines. Currently this use is restricted to small volumes of natural oils.

Meaningful occupation: managing and productive use of bushland, including recreation and tourism, provide many with meaningful occupations. Passive uses – such as by artists, photographers, and naturalists – involve fewer people, but are nevertheless important.

Some luxuries: the uses of sandalwood and boronia oils in the production of perfumes are examples of luxury items produced from native vegetation. In the case of sandalwood, the genetic resource on reserves is currently being utilised in industry development. Some passive uses of natural bushland may be perceived as luxuries, and the use of native plants by hobby gardeners may be perceived either as a luxury or a contributor to mental health.

However the values of natural biodiversity are viewed, it should be clear that they make an important contribution to the quality of human life. In the Wheatbelt Region this is interpreted as meaning that sustainable land use and conservation of natural biological and physical diversity are inextricably linked and interdependent.

While treatment of this topic here has necessarily been brief, the significant effects that philosophical standpoints have on the attitude and behaviour of individuals with respect to biodiversity management are clear from the work of many researchers. See, for example, Callicott *et al.* (1999) and Hull *et al.* (2002).

Appendix 3: Target landscapes: an approach to ranking landscapes for biodiversity conservation in the Wheatbelt.

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Introduction

Biological and functional diversity occur across a range of organisational and spatial scales from genes, species, populations, communities, and ecosystems through to landscapes and larger units (Heywood and Baste 1995). Biodiversity conservation has traditionally focussed on managing species, either through the establishment of a system of protected areas selected to represent biodiversity adequately; or by managing rare and threatened species.

The limitations of an approach based on single species are obvious in the Western Australian wheatbelt. The vegetation is diverse with a high level of endemism (Hopper *et al.* 1996) and there is rapid species turnover across the landscape (Burgman 1988). For example, the current number of threatened flora exceeds 100 species in the wheatbelt and goldfields regions (Brown *et al.* 1998), with several hundred additional species predicted to face extinction as a result of salinity (Keighery and Lyons 2001). About 50 per cent of the bird species present in the wheatbelt have declined in extent and abundance (Saunders and Ingram 1995), and local and regional extinction is ongoing (see, for example, Garnett and Crowley 2000). The high numbers of threatened and declining species reflect a combination of the rich biodiversity of the region and the broadscale processes threatening that diversity. Indeed, the southwest of Western Australia is a global biodiversity hotspot for conservation priorities based on the concentration of endemic plant and vertebrate species and the exceptional loss of habitat (Myers *et al*. 2000).

Of the threats to biodiversity in the wheatbelt, habitat loss and salinity are predominant. Over 90 per cent of the pre-European native vegetation has been cleared and salinity threatens many habitats including some 450 plant species that occur lower in the landscape (Keighery and Lyons 2001). While relatively few species are known to have become extinct through habitat loss alone in the Wheatbelt Region, many species have undergone substantial declines in range and abundance (for example, Kitchener *et al.* 1980a,b, 1982; Saunders and Curry 1990; Saunders and Ingram 1995; Smith 1998). This process of local and regional extinction, known as extinction debt (Tilman *et al.* 1994), continues even though the broadscale clearing of vegetation largely ceased by the early 1980s (Saunders 1989). Contemporary processes such as weed invasion, grazing, waterlogging and salinity are contributing to further habitat loss.

The existing reserve system is clearly inadequate to conserve all elements of the remaining biota (Kitchener *et al.* 1980a, 1982) and in many parts of the landscape there is now insufficient habitat remaining across all land tenures to support viable populations of all remaining species.

In the wheatbelt, where habitat loss and fragmentation is extensive and ecosystem functions are severely disrupted, relying solely on single-species management and a largely *ad hoc* reserve system to conserve biodiversity is not sufficient. There is a clear need to identify and develop new strategies that address the limitations of current approaches to biodiversity conservation in the wheatbelt.

Many new approaches to biodiversity conservation have been developed worldwide. While they can broadly be divided into two groups, they all aim to conserve greater representative samples of the biota than traditional approaches.

The first group focuses on identifying management indicator species, such as keystone (Mills *et al.* 1993), umbrella (Fleishman *et al.* 2000, Poiani *et al.* 2001) and focal species (Lambeck 1997, 1998, 1999). These methods generally assume that meeting the management needs of the indicator species will indirectly conserve many other species (however, see Simberloff 1998; Lindenmayer *et al.* 2002 for arguments challenging this approach). Management strategies may include reserve acquisition, threat management and habitat restoration.

Aspects of the focal species approach (Lambeck 1997) have been adopted by many as a planning tool for biodiversity conservation in the agricultural regions of southern Australia (Lambeck 1998, 1999, Watson *et al.*

2001). Although this method can potentially identify adequate habitat patch sizes required by breeding 'units', it does not adequately resolve how many such patches are required for the long-term viability of a population (Lambeck 1997, 1998). Part of the problem is that patch occupancy models, such as the focal species approach, rely on the assumption that the populations under study are at equilibrium, that is they are not still declining through the process of extinction debt. This assumption is unlikely to hold true in the wheatbelt, particularly for the most area-sensitive species (birds) currently being identified and used as focal species.

The second group aims to improve the efficiency of reserve systems by representing the greatest range of biodiversity assets within the smallest possible area (see Prendergast *et al.* 1999 for a review, Pressey *et al.* 2000). These methods use various measures of biodiversity such as habitat area, species richness, or habitat and landscape diversity to identify the areas important to reserve. However, the emphasis of many current reserve selection processes is on efficient representation of species diversity rather than on conservation of viable populations of biota within the reserve system (Rodrigues and Gaston 2001). However see Cowling *et al.* (1999) for an alternative view. While these approaches traditionally concentrate on developing a reserve system in some form of public ownership, the principles can equally apply to identifying priorities for conservation irrespective of land tenure.

In the context of the wheatbelt, reserve efficiency approaches are problematic. The combination of extensive habitat loss and high species diversity and turnover means that adequate representation within a reserve system would require the conservation of numerous populations, many too small to be viable in the longer term. Conservation of the remaining biota in the wheatbelt requires the management of both public reserves and private remnants as an integrated network.

An alternative approach

A consistent weakness with the approaches described above is that they do not explicitly deal with conserving viable populations, and yet this is the fundamental demographic unit for conserving biodiversity (Smallwood 2001; Margules *et al.* 2002). To address some of the key limitations and gaps in these current approaches a new strategy was developed for the Wheatbelt Region. The main focus of this approach was to identify areas within the wheatbelt landscape where populations of as many species as possible had the greatest chance of remaining viable. Habitat quantity and spatial configuration were the principal factors examined. This landscape scale approach was considered important for the following reasons:

- landscapes within the wheatbelt that contain a relatively high proportion of remnant vegetation are likely to contain high species and community diversity, or have retained large portions of their original biota (particularly birds and mammals);
- for some species, population processes that influence viability operate at a landscape rather than a patch (or habitat remnant) scale: and
- several key threats to population viability, such as insufficient resources, salinity and predation by introduced species operate, and are best managed, at a landscape scale.

Before identifying such landscapes in the Wheatbelt Region it was important to investigate what factors and thresholds were critical to the selection process, including:

1. defining what constitutes habitat for native species in the wheatbelt;
2. investigating how habitat quantity and configuration affect population viability in a fragmented landscape; and
3. understanding how landscape size and location interact with (2) above.

Defining habitat

The lack of sufficient resources[15] is a critical threat to the conservation of viable populations of native biota within the wheatbelt. A surrogate measure of resources is habitat, which can be defined as the "physical environmental factors that permit an organism to survive and reproduce" (Burgman and Lindenmayer, 1998). As it is impractical to define what constitutes habitat for each species, a broader surrogate for resources was needed for this exercise. While resources and vegetation are not synonymous (Miller 2000), there are two reasons why native vegetation was chosen as a surrogate for habitat during the landscape selection process used here.

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[15] Resources in this context are chiefly food, oxygen, water, shelter and access to mates – see Appendix 4.

Firstly, the wheatbelt landscape can be categorised as fragmented (as defined by McIntyre and Hobbs 1999), with the agricultural matrix providing habitat only for generalist native species. Therefore, most native biota are dependent on some native vegetation for their habitat requirements (Saunders and de Rebeira 1991).

Secondly, woody vegetation extent is the only standardised 'habitat' dataset available for analysis across the wheatbelt.

However, there are disadvantages in this approach. For example, using native vegetation as a surrogate for habitat means that some important non-vegetated habitats, such as granite outcrops and salt lakes, are missed in the analysis. In addition, selective clearing of particular vegetation types for agriculture means that current vegetation extent is unlikely to be representative of the pre-European vegetation types. The landscape analysis used here should be repeated when datasets containing finer-grained habitat surrogates, such as vegetation types combined with soil-landscape units, become available. These issues will be addressed in future work.

Habitat quantity and configuration

Having decided that woody vegetation cover was to be used as the resources surrogate, the most important questions then relate to what quantity and configuration of habitat are required to maintain viable populations of native biota. In landscapes where woody vegetation has been extensively cleared and fragmented there has been a tendency to study relationships between the presence/absence of species and the size, shape and quality of individual vegetation remnants, and to ignore or underestimate the influence of broader landscape structure and configuration. Lee *et al*. (2002) observe that past research has assumed the significance of patch effects, however, there is increasing consideration of landscape variables in the more recent literature. The relative importance of patch and landscape scale attributes has also been confounded by the positive relationship between patch size and landscape cover (Lee *et al*. 2002).

One traditional approach to species conservation has been to conserve representative samples of habitat. For example, protected area reservation targets for forest habitats within Australia have been set at 15 per cent (Australian and New Zealand Environment and Conservation Council 1997). However, several authors have questioned the adequacy of similar targets elsewhere for maintaining viable populations (for example, Rodriguez and Gaston 2001).

Several reviews and studies into the relationships between habitat loss and habitat fragmentation on the one hand, with population extinctions (Andrén 1994, Fahrig 1997) and species richness (Mac Nally 1999, Trzcinski *et al*. 1999) on the other, have concluded that it is predominantly habitat loss that leads to extinction and loss of richness. However, below thresholds of habitat loss of 20 per cent (Fahrig 1997) and 30 per cent (Andrén 1994) the effects of fragmentation on population extinctions become increasingly significant. Andrén (1994) noted that whilst such thresholds (30 per cent) are supported both by random sample hypotheses and many real-life studies, responses are also species, landscape and scale specific. Computer modelling by Fahrig (2001) found that thresholds of habitat loss below which extinction probability rapidly increased varied enormously depending upon the variables used. She found that variables such as reproductive rate and emigration had the highest effects on extinction probability, the effects of matrix quality were moderate, and the effects of fragmentation were very small. Recent studies on birds in south-eastern Australia concluded that landscapes retaining at least 30 per cent cover should allow most organisms to persist (Reid 2000), and that below 10 per cent vegetation cover, there is a rapid decline in the number of species of woodland birds (Bennett and Ford 1997). Villard *et al*. (1999), in a study of the effects of forest cover and configuration on the presence/absence of 15 bird species, found that both variables were significant in explaining bird species' distribution. Cooper and Walters (2002), using a similar statistical technique to Trzcinski *et al*. (1999) to separate the effects of habitat loss and configuration indices (patch number, patch size and total edge), examined the effects of woodland loss on the distribution of a single species (brown treecreeper) at a range of landscape scales. They found woodland fragmentation was important in the larger landscapes, while both cover and fragmentation were important in smaller landscapes. Average landscape cover in the smallest landscape was 58 per cent, declining to 17 per cent in the largest landscape. This relationship appears consistent with other studies (for example, Andrén 1994, Fahrig 1997) showing that the effects of habitat fragmentation become more significant when habitat cover in a landscape declined below 20 to 30 per cent.

Flather and Bevers (2002) also found that once landscape habitat amounts exceeded 30 to 50 per cent, the amount of habitat explained almost all the variation in population persistence. Below this threshold, habitat arrangement became equally important. Habitat arrangement was dominated in their modelling approach by an aggregation index, consistent with real life landscapes. At higher levels of aggregation, the amount of habitat required for persistence was lower. Persistence in landscapes below the threshold was strongly correlated to the area and perimeter of the largest habitat patch.

Studies of dispersal success, a fundamental population process for persistence, also identify similar landscape habitat thresholds. For example, a modelling approach by King and With (2002) found that landscape structure and dispersal behaviour affected dispersal success in landscapes with <30 to 40 per cent habitat. However, they also found that even within landscapes where habitat loss exceeded 80 per cent, a high degree of habitat clumping (spatial contagion) increased dispersal success. Spatial pattern had little influence on dispersal success in landscapes where habitat cover exceeded 40 per cent (King and With 2002).

James and Saunders (2001), in developing a framework for terrestrial biodiversity targets for the Murray-Darling Basin, also reviewed the literature on habitat fragmentation, species loss and landscape clearing thresholds. Their report identified significant thresholds of species loss and habitat fragmentation were crossed once 30 per cent, 70 per cent and 90 per cent of the original habitat cover had been cleared.

Many procedures have been developed to identify habitat areas and reserve networks important to conserve biodiversity. These procedures generally use species richness or representativeness as measures of conservation adequacy. Rodrigues and Gaston (2001) highlight that the most widespread reserve selection procedures select the minimum number of sites (minimum area) to represent all of the target species at least once. However, they note that minimum reserve networks are unlikely to ensure long-term persistence or viability. They also found that the minimum percentage area that needed to be reserved to represent all species in a region is highly variable and depends upon levels of biodiversity and endemism, and the size of the selection units.

Pressey and Logan (1998) also make the point that the representation of features in reserves is a means to an end, not an end in itself, and that persistence is the end. They state that designing a reserve network based on an algorithm that emphasises representativeness and efficiency will require sensible decisions on size and configuration at the selection and implementation stage of planning. While Rodrigues and Gaston (2001) also agree that representation is not the same as conservation, they argue:

> "… to ensure that the reserve networks selected fulfil their role of maintaining biodiversity over time, the size of selection units must be one at which the populations of species are likely to persist".

In summary, numerous studies have examined the effects of habitat loss and fragmentation on species extinction. These studies have revealed that species extinction thresholds relate to the proportion of habitat loss and fragmentation within a landscape. However, we also need to understand the relationship between these thresholds and landscape size. For example, a landscape of 100 hectares that contains 50 hectares of habitat (50 per cent) is unlikely to support a viable population of a small resident bird species. However a 40,000-hectare landscape with 20,000 hectares of habitat (still 50 per cent) might support a viable population of the same species.

Landscape size and position

Several studies of birds in both Australia and overseas have examined the responses and relationships between the presence or absence of individual species and species richness on the one hand, with the proportion of remaining vegetation cover in landscapes of various sizes. These studies provide some indication of the scale at which processes critical to persistence of bird populations operate in relation to landscape patterns. Processes such as daily foraging and breeding operate at territory and patch scales; while longer-term population processes of local extinction and recolonisation operate across larger landscape scales. Therefore, identifying the landscape scale needed to encompass all the population processes is paramount.

Cooper and Walters (2002) chose landscape scales ranging from 0.78 km^2 to 63.6 km^2 to examine the effects of woodland loss and fragmentation on the distribution of brown treecreepers. The landscapes were defined by circles with radii from 0.5 to 4.5 kilometres in 0.5-kilometre increments centred on occupied and unoccupied sites. Landscape patterns in the smallest and largest landscapes had clearer effects on site occupancy than at intermediate scales, possibly reflecting scales of foraging and dispersal (Cooper and Walters 2002). In this study, landscapes in the order of 60 to 70 km^2 with at least 17 per cent vegetation cover seemed to be appropriate selection units to identify and manage viable populations of the brown treecreeper.

Two other studies, one in New South Wales (Reid 2000) and one in Victoria (Bennett and Ford 1997), investigated the relationship between the richness of woodland bird species and the proportion of woody vegetation remaining in landscape grids of approximately 300 km^2. At this scale both studies found strong relationships between the richness of woodland bird species and woody vegetation cover. Reid (2000) suggested that the retention of 30 per cent of any particular vegetation type in these landscapes should allow most organisms dependent on that ecosystem to persist. He also concluded that the retention of landscapes (~300 km^2) with at least 50 per cent vegetation cover was vital to the regional persistence of many species in agricultural regions. Bennett and Ford (1997) showed that below 10 per cent vegetation cover the decline in the number of species persisting in landscapes of ~300 km^2 is rapid, and recommended the retention of at least 10 per cent cover as the minimum goal to prevent further dramatic species losses. Trzcinski *et al*. (1999) found that at a landscape scale of 100 km^2 records of most breeding forest birds were significantly correlated with forest cover, and not significantly correlated with fragmentation effects. However, it should be noted that in these three studies the landscape scale was selected because the datasets of bird records used in the analyses were collected and compiled on a grid basis.

Villard *et al*. (1999) in a study of the effects of forest cover and configuration on the presence/absence of 15 bird species in 6.25 km^2 landscapes in Ontario, Canada, found that both variables were significant in explaining bird species' distribution. The landscape size was considered large enough to encompass the breeding dispersal of most species of forest-dwelling passerines.

Ideally, the scale of landscape and patch is linked to a meaningful demographic unit for the organism(s) under investigation (McGarigal and Marks 1994). For the purposes of this process the term landscape has been defined from Forman (1997) as:

> "a mosaic where the mix of local ecosystems or land uses is repeated in a similar form over a kilometers-wide area".

However, an effective landscape for biodiversity conservation is one that contains sufficient habitat to support viable populations of all extant resident species. Smallwood (2001) provides a more detailed discussion of the spatial area of habitat needed to support functionally significant demographic units. Other factors influencing the choice of an appropriate landscape scale include the extent of the study area, patch size and grain in relation to the units of observation (McGarigal and Marks 1994).

Boundary effects also influence choice of landscape size. For example, calculating the proportion of habitat within a landscape may be biologically unrealistic if a large habitat patch occurs immediately outside the landscape boundary. The magnitude of this problem is a function of scale, and the larger the ratio of extent (landscape) to grain (patch) the less likely results will be influenced by boundary effects (McGarigal and Marks, 1994). There is an extensive coverage of this topic, termed the modifiable areal unit problem (MAUP), in the geographical, and to a lesser extent the landscape ecology literature (for example, Openshaw 1984, Jelinski and Wu 1996).

Building a model for the wheatbelt

Using the principles from the literature reviewed above it was possible to develop a simple set of minimum criteria to identify landscapes with a reasonable probability of meeting our management goals and objectives, that is, the retention of viable populations of all extant species within a landscape. The criteria were:

- landscapes should contain a minimum of 30 to 40 per cent habitat to minimise the risk of population extinction; landscapes below a threshold of 10 to 20 per cent remaining habitat show increased rates of species loss due to the combined effects of habitat loss and fragmentation. In work to date 25 per cent has been used as an important threshold because it lies above the lower threshold of 10 to 20 per cent, allows for the possibility of restoring habitat to bring important areas up to the 30 to 40 per cent threshold, and is a conservative approach in a highly cleared landscape;
- for more mobile groups of organisms such as birds, landscapes should be in the order of 100 to 300 km^2 to maximise population viability. Other less mobile groups of organisms should be able to persist across smaller scales or within subsets of these landscapes; and
- the distribution of habitat in landscapes should tend towards a higher degree of clumping (spatial contagion).

Landscape 'Polygons'

A geographic information system (GIS) was used to identify areas of the wheatbelt that contained a certain proportion of habitat and to ensure that the process was accurate and repeatable. The only appropriate spatial 'habitat' dataset available for the analysis showed the presence/absence of remnant native vegetation. This dataset was classified from LANDSAT TM imagery with a pixel resolution of 625m^2, and verified using 1:25,000 scale aerial photography. The classification error rate of the final dataset was acceptable for this analysis.

The issues of landscape size, shape and placement were addressed using a series of 12 hexagon grid themes (comprised of interlocking 10,000-hectare hexagons). These were created using the *Patch Analyst 2.0* extension for *ArcView 3.x*. Each of the twelve grids was slightly offset from the others, with each hexagon representing a landscape. Hexagons were chosen as the appropriate landscape shape as they are the closest packing shape to a circle, and therefore minimise edge effects (Rempel *et al*. 1999). Twelve offset hexagon grids were used to reduce further edge effects caused by the arbitrary placement of the hexagonal grid in relation to the underlying vegetation dataset. Each of the 12 hexagon grid themes was separately intersected with the remnant vegetation theme to produce 12 new datasets with each hexagon now containing a set of the underlying remnants.

It was then possible to run a standard query on each of these new datasets to identify hexagons that contained a certain proportion of remnant vegetation. This process was repeated for each of the twelve intersections, and the results merged to produce a single map. Merging the query results for all twelve intersections produced landscapes that were no longer hexagonal in shape, and in most instances were much bigger than 10,000 hectares in area. The query and merge process was repeated to identify landscapes greater than 10,000 hectares in extent, and containing various proportions of remnant vegetation (10, 15, 20, 25 and 30 per cent) across the Wheatbelt Region. Figures 5 and 6 are examples of the types of results obtained from analyses for landscapes >10,000 hectares with >25 per cent vegetation cover within the Wheatbelt Region and Avon Wheatbelt 2 IBRA Sub-region respectively. These data, together with other biophysical and social process information will, in other work, be combined and evaluated by staff to identify the priority landscape polygons for more detailed planning and management programs.

Figure 5: Landscapes >10,000 hectares with >25 per cent remnant vegetation in the Wheatbelt Region

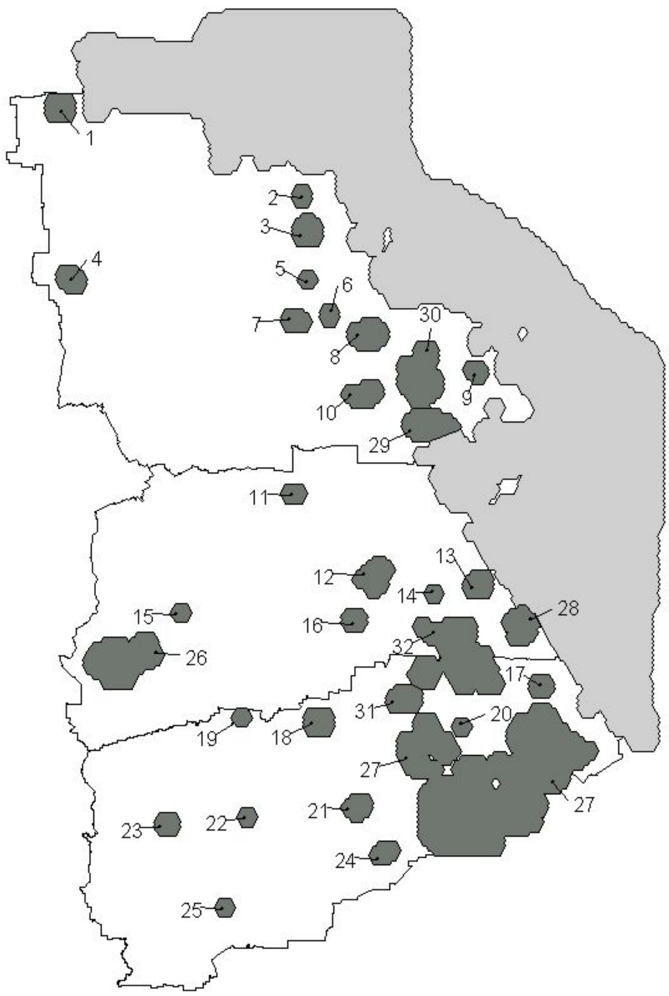
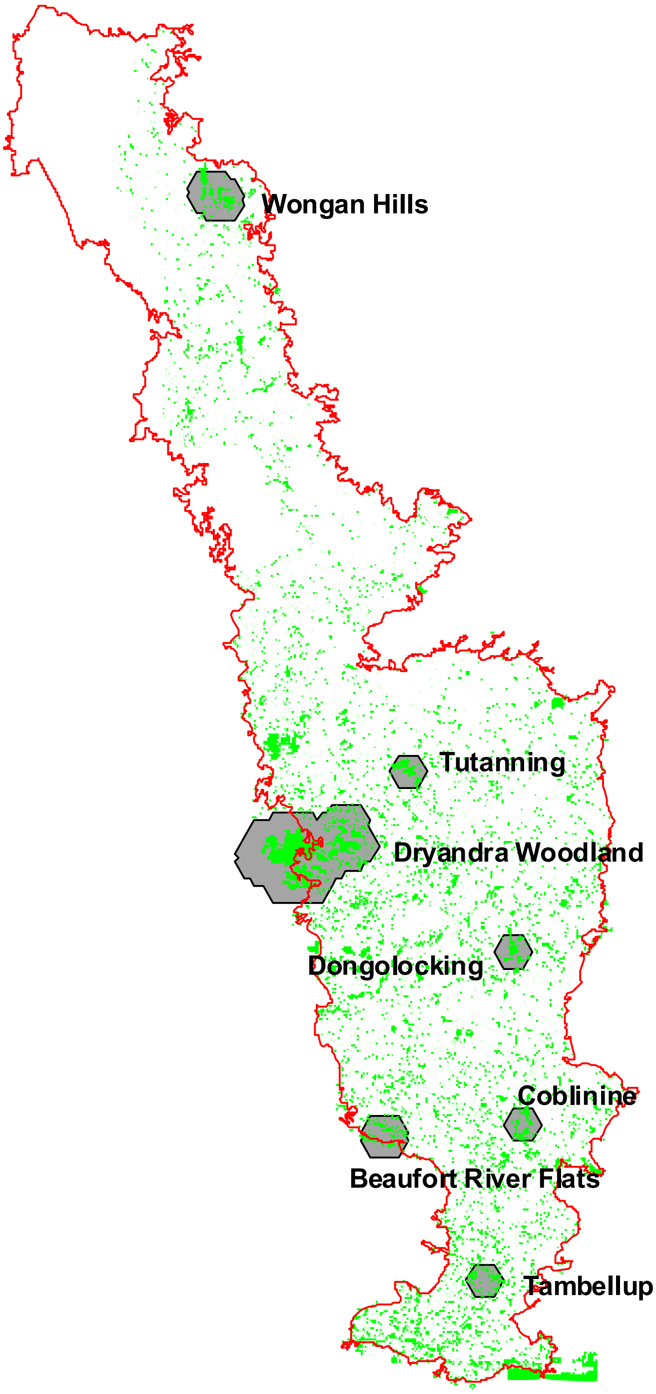


Figure 6: Landscapes >10,000 hectares with >25 per cent remnant vegetation in the Avon Wheatbelt 2 IBRA Sub-region.

(Green areas show remnant vegetation, grey identifies target landscapes)



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Appendix 4: Threats - working definitions

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Background

Management for biodiversity conservation fundamentally involves preventing loss of diversity. Even reconstructing natural biodiversity – for example, by translocating native mammals back to an area from where they have become locally extinct – is largely about ensuring there are sufficient representative samples to secure long-term conservation of the species in question. If there are no pressures, actual or potential, on biodiversity conservation, then there is no reason for management.

The concept of threats has been widely used to describe these pressures. See, for example, Burgman and Lindenmayer (1998). However, threats are not well defined in the literature (see Appendix 1 for the definition used in this document). The Nature Conservancy (2000a, 2000b) makes a useful distinction between two components of threat by distinguishing the source of a threat from the actual stress it causes. For example, toxins from cyanobacteria (a stress) may kill waterbirds, with nutrients in agricultural run-off the source of the stress. The degree of threat, under this scenario, is represented by a combination of probabilities including the likelihood that a source will produce eutrophication, and the probability that sufficient toxins will be produced and cause bird deaths.

However, the lists of sources and stresses produced by The Nature Conservancy (2000b) do not always clearly discriminate between the two factors. For example, they list both toxins and nutrient loading as potential stresses. Furthermore, a closer examination of the above example concerning waterbirds quickly shows that much more complex relationships than simple binary ones may be involved. That is, where does one discriminate source from stress in the following chain of events?

Lack of information concerning soil nutritional status and appropriate fertiliser use ⇒ overuse of agricultural fertilisers ⇒ combined with a one in 20 year rainfall event ⇒ nutrient rich sediments carried to wetland ⇒ cyanobacteria 'bloom' releases toxins ⇒ waterbirds ingest toxins ⇒ chemical reactions within birds causes death.

While it is possible to define stresses in terms of actual physical and chemical changes wrought in individual organisms, such a reductionist approach by itself will rarely be helpful for conservation managers. Therefore, the approach adopted here is to encourage managers to think through the description of threats at two levels. Firstly, what are the factors in an organism's immediate environment that directly affect its probability of surviving and reproducing? This question can be answered in a scientifically rigorous manner, and can be used to generate a checklist of factors with which managers need to be familiar. And secondly, under what broad category of threat is it useful to deal with factors? This question is generally used to generate categories of threats that are a mixture of scientific rigour and management convenience, and thus the categories will vary depending on the perspective of the manager. Both these issues are dealt with below.

Factors affecting survival and reproduction

A range of factors in the immediate environment of an organism determines whether it will survive and reproduce. These can be broadly grouped, using Andrewartha (1971) as a starting point, into:

- resources;
- predation and disease;
- physical and chemical factors in the immediate environment of an organism;
- malentities; and
- availability of mates (for organisms reproducing by sexual means).

Table 7 summarises the key factors within each of these groups. The value of the table is that it provides managers with a checklist of factors in the environment of organisms that affect their survival and reproduction. These factors may interact in quite complex ways, and be either synergistic or antagonistic. For the most part these factors represent stresses in the sense used by The Nature Conservancy (2000a), and directly affect organisms.

Where environmental factors favour the survival and reproduction of individual organisms, there is one additional factor that managers must take into consideration. This is that, to sustain viable populations of organisms, there must be sufficient biophysical resources to support the required number of reproductive units. Table 7, which is aimed at individual organisms, does not identify this issue; however, it is dealt with below under the categories of threats as point (9).

Table 7: Factors affecting survival and reproduction of individual organisms.

Group of factors	Factor	Explanation
Resources These basic needs support the life of individual organisms. They must be in sufficient supply for survival and reproduction – under normal circumstances they have a lower, quantity threshold, but not an upper threshold. This is one of the features that distinguish resources from physical and chemical tolerances. Note that some factors listed here – such as life medium and substrate – overlap with physical and chemical factors listed below. However, they are included here as they represent a resource that becomes an issue when they are below a particular quantity, rather than needing to be within a specific range of thresholds for survival and reproduction.	Light	Energy source for phototrophic organisms and also in some chemical reactions to produce nutrients (for example, ultraviolet light for human production of vitamin D).
	Food	Energy source and organism structure. Includes amino acids, carbohydrates, lipids, and various organic and inorganic chemicals required to sustain life.
	Water	Dietary, or as taken up by plants and other organisms.
	Oxygen	Used by organisms to generate energy.
	Carbon dioxide	Required by plants to generate carbohydrates.
	Digestive aids	Includes kaolin clay used by cockatoos to counteract toxins, gut flora that aid digestion, and gizzard stones.
	Life media and substrates	All organisms need appropriate life media, such as air, water, and so on. Also, terrestrial and many aquatic organisms require a specific substrate. For example, lichens on granite rocks, specific soil requirements of plants (where soil can be both substrate and medium), settling sites for larvae of mussels, etc.
	Shelter	This could be considered as a second order factor, rather than a primary one, because shelter is generally used as a protection against predators or physical factors in the environment.
	Dispersal aids	Many organisms require dispersal agents, and this may be an animal, but may also be a raft or some other agent. As with shelter, this could be considered a secondary factor that provides access to resources.
	Other	Rubbing posts may be used to squash ticks, etc.
Predation/disease/parasites Predators and pathogens directly threaten organisms by causing death, or by causing sufficient debilitation to threaten the survival or reproduction of an organism.	Predation	Used here to include herbivory, as well as the eating of one animal by another.
	Disease and parasites	Death/damage may result as a form of eating, or be caused by toxins released by the disease organism or parasite.
	Direct Destruction	In addition to the above, humans and other animals deliberately destroy plants and animals other than as a predator/herbivore. Examples include clearing vegetation to make agricultural land and harvesting kangaroos for their hides. While these acts could be interpreted as a form of resource competition, they are more appropriately incorporated in this category.

Malentities Occurs when organism A inadvertently causes the death of organism B, and where B is not a direct environmental factor in the life cycle of A. (See Andrewartha 1971 for a more detailed explanation.)		For example, springtails (*Collembola*) may drown in water contained within a cow's footprint. The footprint is the malentity, the cow is not affected by springtails, and they are effectively outside the cow's direct environment. The cow had no intent to act in a way that drowns springtails. Alternatively, this category could be considered superfluous. For example, in the case of the springtails, the proximal cause of death is drowning, an excess of moisture (see below).
Physical and chemical factors Organisms come into direct contact with a range of chemical and physical factors in their environment. Survival and reproduction will generally depend on these factors lying either within a specific range – for example, as in the case of moisture and temperature – or on these factors not exceeding certain intensity thresholds (such as in the case of fire). The role of tides, lunar cycles, etc. in setting biological clocks could be separated as a new category; however, they are retained here given that they represent physical aspects of the environment.	Temperature	Organisms survive and reproduce within a specific range of temperatures (which may in some animals be changed through acclimation). Outside this range, the survival and reproduction of animals may be affected. Extreme temperatures will generally be lethal. Freezing – for example, frost death amongst plants – is a specific case of temperature effects as is thermal pollution.
	Moisture	Explanation similar to that for temperature. However, note that moisture could be considered a secondary factor that influences dietary requirement for water. Also, while an excess of moisture can be lethal (drowning), death is via impacts on oxygen absorption.
	Light	Explanation similar to that for temperature. Prolonged exposure to light may be lethal for some organisms. For example, frogs may be killed by prolonged exposure to ultraviolet-B radiation in light (Broomhall *et al*. 2000). Note also that light, for some organisms, has an important role in synchronising life cycles within species, or with resources.
	Chemical	Organisms need the environmental chemistry, including salinity, pH, etc., to be within certain ranges for survival and reproduction. Pesticides, oil spills, toxins in the external environment, etc., are also included here.
	Fire	While this could be considered a specific case of a temperature factor, it also involves chemical factors and effects. From a manager's viewpoint, it is useful to consider it separately. Note that, when listed here, it is the direct physical impact of fire that is under consideration. Many other effects of fire occur via impacts on resources.
	Other	Tides, lunar cycles, etc. may all play important roles in maintaining tolerance conditions, or synchronising elements of life cycles essential to survival or successful reproduction.
Lack of mates (in the case of sexually reproducing organisms)		Self-explanatory.

Categories of threat

While the above table provides a valuable checklist and diagnostic tool, most managers find it more convenient to categorise management strategies according to commonality of management approach, rather than by factors directly affecting organisms. For example, exotic animals may detrimentally affect native animals through a range of the factors listed in Table 7 including direct predation, competition for a food resource, or because of the lack of a shelter resource for the native animal. These, in terms of the above table, are all very different factors. However, from the manager's perspective they all require the control of an exotic animal, and this is the preferred organising theme from a manager's viewpoint. Similarly, chemicals are one of the factors listed above as affecting the survival and reproduction of animals. From a management perspective, it is convenient to group chemical events caused directly by humans – such as pesticides and oil spills – as one group, and those – such as salinity and eutrophication that are caused by a major dysfunction in biogeochemical cycles – as a separate group.

Based on these considerations, officers in the Wheatbelt Region have, to date, found the following arrangement of threats to be the most useful. Other groupings have been tried, but have all contained too many contradictions. Note that the management issues are listed as examples only – they are not intended as a comprehensive list.

1. *Altered biogeochemical processes*: Management issues include:
a. hydrological processes, particularly salinity and negative impacts of drainage;
b. nutrient cycles, including eutrophication; and
c. carbon cycle and climate change.

2. *Impacts of introduced plants and animals*: Management issues include:
a. weed control;
b. control of feral predators;
c. preventing new introductions of damaging species;
d. grazing of remnants by stock; and
e. competition for food and shelter.

3. *Impacts of problem native species*: Management issues include:
a. the dramatic increase in numbers of some parrots, due to habitat change, resulting in grazing damage and competitive exclusion of some other native species; and
b. defoliation by scarab beetles and other damage by excessive numbers of native herbivores.

4. *Impacts of disease*: Management issues include:
a. dieback (*Phytophthora* spp); and
b. armillaria.

5. *Detrimental regimes of physical disturbance events*: Management issues include:
a. fire regimes that may lead to local extinction of one or more species;
b. cyclones; and
c. drought.

6. *Impacts of pollution*: Management issues include:
a. herbicide use and direct impacts on plants, including effects of fungicides;
b. pesticide surfactants and impacts on vertebrate reproduction; and
c. oil and other chemical spills.

7. *Impacts of competing land uses*: Management issues include:
a. recreation management;
b. management of agricultural impacts;
c. management of consumptive uses (wildflower cutting, timber cutting, etc.);
d. management of illegal activities; and
e. management of mines and quarries on bushland.

8. *An unsympathetic culture*: Management issues include:
a. attitudes to conservation; and
b. poor understanding of nature conservation values and their contribution to human quality of life.

9. *Insufficient resources to maintain viable populations*: The management issue here is:
Ensuring that there are sufficient resources (see Table 7), if threats (1) to (8) inclusive are held constant, to allow viable populations of organisms to persist. This includes sufficient space for habitat replication so that disturbance regimes, see threat (5) above, may be managed. However, the basic resources are food, water, oxygen, shelter and access to mates. Revegetation to create buffers and corridors, habitat reconstruction, and regeneration of degraded areas are important management techniques in this context.

Appendix 5: Threats and management activities - Wheatbelt Region

In the Wheatbelt Region, the Department of Conservation and Land Management's expenditure is structured against the performance measures shown in the table below. These tables are individually prepared for expenditure in relation to various categories of biodiversity assets. For example, for specific managed landscapes, individual or groups of threatened species, particular threatened ecological communities, groups of conservation reserves, and so on.

Planning and documenting expenditure in this way has a range of advantages. Firstly, for an individual asset, this format closely links expenditure, performance measures, management activity, and threat being managed to the goal for that asset. Linking these elements ensures that the full range of threats is considered during planning, and allows operational personnel to understand why they are undertaking management action. That is, they may clearly link their management activity and outputs with tackling a specific threat to goal achievement in relation to a particular asset.

Secondly, because the threats, management activities and outputs are consistent across all assets, it is possible to accumulate data at any level across all the relevant tables, either by asset type, or by threat type, or by activity type, or by some combination of these. This makes the structure a very powerful planning instrument.

Thirdly, this format enables management efficiencies to be calculated. For example, the cost of producing the same output – such as revegetation to control excess water – can be calculated for different areas and projects.

Threats	Work activities	Performance measures (Note that in practice, expenditure is also recorded against each work activity.)
Lack of ecological resources to support viable populations	Expansion of conservation estate through land purchases. Current efforts in this area are generally focussed on purchasing lands that enhance long-term viability of existing reserves and remnant systems.	Number of land parcels inspected
		Number of land parcels purchased
		Total area of land purchased
	Biological surveys to identify lands (but not those for private land purchase) that should be incorporated into the conservation estate, used for seed orchards, revegetated, or accorded better protection for salinity control.	Number of areas surveyed
		Number of recommendations completed (at regional level)
		Total area agreed to come into conservation estate
	Biological surveys (e.g. vegetation and floristics, mammal surveys, rare flora surveys and monitoring) as a basis for monitoring and planning.	Number of surveys
	Creating buffers (including habitat expansion) for remnant vegetation, but not including use of commercially prospective species. Involves use of funds for works on private property to protect biodiversity values, and includes fencing of revegetation.	a. Number of sites
		b. Number of seedlings
		c. Area of buffers
		d. Total kilometres of fencing
		e. Total number of landholders involved
	Creating corridors (not including commercially prospective species) connecting remnant vegetation. Involves use of funds for works on private property to protect biodiversity values, and includes fencing of revegetation.	a. Number of sites
		b. Number of seedlings
		c. Area of corridors
		d. Total kilometres of fencing
		e. Total number of landholders involved
	Using commercially prospective species to buffer or create corridors.	a. Number of sites
		b. Number of seedlings
		c. Area planted
		Total kilometres of fencing
		Total number of landholders involved
	Rehabilitation of degraded areas on Crown lands including: • Rehabilitation of historic quarries. • Revegetation of disturbed parts of recreation sites in conjunction with other works funded under recreation program. • Removal of rubbish and site rehabilitation. • Revegetation of cleared areas.	Number of sites rehabilitated
		Area rehabilitated
		Number of reserves involved (note, individual reserves should only be recorded once)

	Improved protection and management of native vegetation on private properties including: • Fencing of remnant vegetation on private property. • Coverage of private remnants by conservation covenants.	Kilometres of fencing
		Number of remnants
		Area of remnants
		Number of landholders involved
		Number of sites covered
		Area of sites covered
	Research other than listed above, and includes the development of management polygon approach, focal species approach and related activities.	List (separately) of reports and investigations
Detrimental regimes of physical disturbance events, such as fire, cyclone, drought, flooding. At this stage, fire is the only disturbance proposed for management. All activities relate to fire management.	Planning and liaison.	Separate written list of plans and other documents
	Fire suppression.	Number of wildfires in district/region
		Area burnt in district/region
		Number of wildfires attended outside district/region
	Construction and maintenance of fire-access tracks.	Length (kilometres) constructed
		Length (kilometres) maintained
		Number of reserves on which construction work undertaken
		Number of reserves on which maintenance work undertaken
	Fuel reduction.	Area treated
		Number of reserves treated
Impacts of introduced plants and animals.	Weed control – bridal creeper.	Number of sites treated
		Area treated
		Number of reserves treated (note, individual reserves should only be recorded once)
		Number of private property sites
	Weed control – other.	Number of sites treated
		Area treated
		Number of reserves treated (note, individual reserves should only be recorded once)
		Number of private property sites

	Rabbit control.	Number of sites treated
		Area treated
		Number of reserves treated (note, individual reserves should only be recorded once)
		Number of private property sites
	Pig control.	Number of sites treated
		Area treated
		Number of reserves treated (note, individual reserves should only be recorded once)
		Number of private property sites
	Fox control.	Number of sites treated
		Area treated
		Number of reserves treated (note, individual reserves should only be recorded once)
		Number of private property sites
Impacts (on conservation values) of native plants and animals.	Control of plague locusts.	Area treated
Impacts of disease.	Phytophthora management.	Number of reserves surveyed
		Number of sites sampled
		Number of sites treated
	Armillaria and other diseases.	Number of reserves surveyed
		Number of sites sampled
		Number of sites treated
Inappropriate use of pesticides, oil spills, chemical spills.	No proposed work in this area in 2000/01.	

Altered biogeochemical processes *Note that salinity and waterlogging control is the only activity shown. Nutrient stripping and carbon sequestration have not been included, but may be later.*	Contribute to the development of improved drainage assessment, practice and policy.	Number of Notices of Intent to drain processed
	Revegetation (generally of cleared areas on private property) with the main objective of hydrological control. Includes fencing. Not including commercially prospective species.	Land conservation plantings
		a. Number of sites
		b. Number of seedlings
		c. Area planted
		d. Kilometres of fencing
		e. Number of landholders involved
	Revegetation with commercially prospective species (generally of cleared areas on private property) with main objective of hydrological control. Includes fencing.	a. Number of sites
		b. Number of seedlings
		c. Area planted
		d. Kilometres of fencing
		e. Number of landholders involved
	Engineering works on Crown lands to protect public asset values.	List (separately) of investigations, reports
		Number of sites treated
		Length of structure; or
		Area treated
	Engineering works on private property to protect public asset values.	List (separately) of investigations, reports
		Number of sites treated
		Length of structure; or
		Area treated
		If appropriate, number of de-watering bores
	Monitoring and research/investigations (other than listed for particular project areas above).	List (separately) of investigations, reports

Inappropriate culture.	Management of recovery and related committees, input to catchment planning, liaison with local authorities and all other groups.	Number of meetings
		Number of groups dealt with
	Communication, education, general training of external audiences.	Number of groups dealt with
		Number of interpretive items
		Number of media releases
	Volunteer management.	Number of volunteers
Competing resource use.	Mining.	Number of applications dealt with
		Number of active mines in current year
	Illegal activities (prosecutions/investigations).	Number of breach reports prepared
		Number of prosecutions
		Number of successful prosecutions
		Number of days spent on patrol
	Damage permits for kangaroos and other problem animals where problem relates to impinging on a resource use other than conservation.	Number of damage permits
	Consumptive and productive use of native biota (includes wildflower picking, apiary sites, firewood, aviary licences, etc.).	Number of inspections
		Number of permits issued
	Notices of intent to clear.	Number dealt with
	Recreation.	See Parks and Visitor Services
	Other proposed uses of bushland not listed above (Telstra, water pipes, bridges, etc.)	Number dealt with
	Fauna rescues.	Number dealt with

Appendix 6: Recovery goals and targets - the woylie (*Bettongia penicillata ogilbyi*)

This example was prepared for the Avon Catchment Council (Wallace *et al.* 2002).

Goal: to halt or reverse the decline of the woylie in the wild and ensure its future chance of survival (and if appropriate, expansion).	Target: to reduce the threatened status of the woylie from "critically endangered" to "vulnerable".	Outcome: achieved – the threatened status of the woylie has been formally reduced. This occurred through the evaluation of the animal's status against specific (IUCN) criteria.
Specific objectives, to: 1. Determine the current wild distribution of the woylie in WA. 2. Establish a population of woylies on a mainland area in South Australia without using predator-proof fences. 3. Develop prescriptions for the maintenance and extension of woylie populations in multiple-use forest in WA. 4. Ensure that translocated woylie populations maintain genetic variability. 5. Review the conservation status of the woylie, using internationally accepted criteria, and recommend changes if necessary.	Recovery criteria The criteria set by the recovery team for successfully achieving the objectives were: 1. At least six populations of woylies, each occurring in areas of at least 1,500 hectares of suitable habitat and each increasing in density (and areas where there is contiguous suitable habitat) or plateau at a trap-success rate greater then 7.5 per cent. 2. Clarification of the status of the woylie in conservation reserves and State Forest of the south-west of WA. 3. Establishment of experiments to determine the effects of timber harvesting (at Kingston Forest) and fuel-reduction prescribed burning (at Batalling Forest) on woylies and commitment in a Wildlife Management Program to modify forest management prescriptions to ensure compatibility with maintaining woylie populations. 4. Maintenance of two island populations, on Wedge and St Peter Islands (South Australia). 5. Establishment of at least one mainland population in addition to the Yookamurra population (South Australia).	Good progress against all recovery criteria – see report by Start *et al.* (1995), Start and Burbidge (1996) for more details.
The actions implemented by the Recovery Team comprised: 1. Control of exotic predators, particularly foxes. 2. Survey and establishment of monitoring programs. 3. Range expansion (where feasible) and translocation. 4. Set up experiments to determine the effects of forest management practices. 5. Genetic assessment and re-stocking. 6. Employment of a Scientist in South Australia. 7. Education and publicity.	Targets for most of these are self-explanatory. For others, such as (1), intensity of baiting was increased until predation pressure on woylies released.	Expressed through level of achievement of recovery criteria.