DONGOLOCKING PILOT PLANNING PROJECT FOR REMNANT VEGETATION

PHASE I — FINAL REPORT

NOVEMBER 1998

CSIRO

Environment Australia

Department of Conservation and Land Management

Land & Water Resources Research & Development Corporation

Agriculture Western Australia

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Edited by K. J. Wallace

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- CSIRO Wildlife and Ecology; and
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While authorship is acknowledged at the beginning of each section of the report, group discussions were important in the development of ideas.

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SUMMARY

The broad aim of the Dongolocking Project, funded by State and Federal agencies, is to establish a planning process for the protection of remnant vegetation including management of associated revegetation. Work at Dongolocking has produced (this report) a generic framework for planning, and future work will further develop and then test the planning process through implementation of on-ground works.

This collaborative project draws on local knowledge as well as published information and expertise within the Department of Conservation and Land Management, CSIRO Division of Wildlife and Ecology, and Agriculture Western Australia.

At Dongolocking, the project is based on nature conservation objectives as other local land use goals, particularly sustainable, profitable agriculture, are essential to nature conservation although the corollary is not necessarily so. This important issue is treated in more detail on page 15.

This report documents phase I of the Dongolocking project. In this phase, major tasks have been to:

1. Document project objectives and the planning methods. These sections are comparatively straight-forward. However, the challenges and constraints associated with aiming to conserve all remaining native species are discussed, and the need to assign probabilities to goals that deal with dynamic systems emphasised. The process of assigning a probability to achievement of the management goal, as discussed in the Appendix, is an important "first" for projects such as this in Western Australia.

2. Develop a landscape planning framework for integrating land use goals and management (page 11). This framework highlights significant components of the agricultural environment and guides their integration. In addition to a framework for integrating land use goals, it became clear during the project that a framework was also needed for nature conservation at a landscape scale (page 17).

3. Describe and document the relevant environmental components of the project area. Apart from the challenge of bringing together a wide range of biophysical information essential to planning, this has involved writing a most interesting synopsis of the local history (page 35) and a survey of landholders to establish their views and needs (page 45). While time limitations affected the level of community involvement, the survey of landholders has proved very valuable and will provide significant guidance for the next phase of the project.

4. List and describe the threats (page 53) to achieving the project's primary on-ground goals. There has been surprisingly little documentation of threats at a landscape scale for a range of goals, and no list was found in the literature that provided detail equivalent to that in this report. As mentioned above, the attaching of probabilities to these threats is rarely, if ever, attempted with Australian projects. It proved a valuable exercise, and should be developed further to assist both planning and management.

5. Develop a landscape scale revegetation plan aimed at conserving the remaining natural biodiversity at Dongolocking (page 59). This is a core part of the project, and the process used, which was first developed for the Wallatin Catchment, should provide a fundamental methodology for landscape scale nature conservation planning.

6. Outline the work proposed in phase II of the project. This second phase will focus on working with landholders to develop farm scale revegetation plans that meet their, and landscape, needs. Comments on issues such as cost-sharing, including a proposed basis for allocating revegetation costs (page 88), should stimulate wider discussion and debate.

7. Outline implications for other work from phase I (page 93). A number of issues, including limitations on planning at various scales and planning for management of remnant groups are covered in this section. Conclusions concerning the limitations of planning at regional scales, and the value of a management "polygon" approach for nature conservation should promote discussion of a range of planning and nature conservation management issues.

by Ken J. Wallace

Project History

Project Development and Funding

Dr Peter Bridgewater, then Head of Environment Australia's Biodiversity Group, wrote to Australian land management agencies in late 1996 seeking Expressions of Interest in developing a pilot project for planning remnant vegetation management. Funding for developing pilot projects was offered by Environment Australia (EA) in conjunction with the Land and Water Resources Research and Development Corporation (LWRRDC).

On 10 December 1996 a meeting was held at the Como offices of the Department of Conservation and Land Management (CALM) to discuss a proposal submitted by CALM. Those in attendance were:

Dr Andrew Campbell, Assistant Secretary, Sustainable Land and Vegetation Branch, EA

Dr Richard Hobbs, CSIRO Wildlife and Ecology

John Lumb, Sustainable Land and Vegetation Branch, EA

Dr Phil Price, Executive Director, LWRRDC

Ken Wallace, CALM.

A representative from Agriculture Western Australia (AgWA) was not available to attend on the day.

During this meeting the national objectives of the project (see section below on National Level objectives) were explained, and details of what could be delivered through work at Dongolocking discussed. The very short time available for such a complex project was acknowledged by all present. In this context it was agreed that if outputs from the first phase of the project (up to 30 September 1997) were acceptable, then funding may be granted to complete the full planning project and to begin implementation of on-ground works.

It was agreed that the Dongolocking proposal should be further developed and submitted for funding.

Subsequently, a revised project outline was submitted by CALM, and the project received endorsement from LWWRDC, the contracting agency (letter dated 15 January 1997).

Selection of Project Area

CALM's selection of the Dongolocking project area (see Maps 1 and 2) was based on:

- The great diversity of remnant types in relation to size, vegetation types, and connections with other bushland in comparison with other remnant groups in the wheatbelt. Within the 28 900 ha study area, remnant native vegetation totals about 5 290 ha. This includes 3 580 ha of Crown reserves, including 3 450 ha in nature conservation reserves, and 1 710 ha of remnants on freehold land.

- The diversity of fauna persisting at Dongolocking. This includes mammals - such as the red-tailed phascogale (*Phascogale calura*), brush wallaby (*Macropus eugenii*), and recently re-introduced quenda (*Isoodon obesulus fusciventer*) - and birds - such as the western yellow robin (*Eopsaltria griseogularis*), southern scrub robin (*Drymodes brunneopygia*) and rufous treecreeper (*Climacteris rufa*) - that have disappeared from many agricultural districts in Western Australia. The persistence of these animals, the considerable diversity of flora, and the high level of connectivity make the Dongolocking group an outstanding group of remnants for nature conservation. In addition, it was considered that the range of species sensitive to remnant degradation would aid subsequent monitoring of project outcomes.

- Compared with most other wheatbelt sites, the biota of the area is well documented.

- Led by local Terri Lloyd (Lloyd 1995), local farmers have helped establish and monitor revegetation corridors. Thus there is a resource of interested, local land managers.

- The area is within reasonable proximity (<1 hours drive) of Narrogin and Katanning, important bases for staff from both CALM and AgWA. This allows adequate agency servicing of the project area.

- Dongolocking lies within 15 km of Toolibin Lake Catchment, an important recovery catchment based on a Ramsar wetland. Significant work is occurring in the Toolibin Catchment to recover the Lake which is at serious risk from severe salinisation. Therefore, this project provides a valuable opportunity to develop two important case studies in close proximity.

- Dongolocking is nearly linked, via a railway corridor containing excellent stands of native vegetation, with the Toolibin Catchment. There is also potential to physically link Dongolocking with important conservation areas to the east (Tarin and North Tarin Rock Nature Reserves), and townsite and water reserves to the north-east in and near Harrismith. Thus Dongolocking provides an opportunity to develop a landscape scale case study that has potential links to other important conservation areas.

- Because salinity is primarily affecting low-lying areas, there has been a tendency for work to concentrate on these sites. However, there is a need to treat the whole landscape to control groundwater rise. Work at Dongolocking, which lies largely in the upper catchment, provides an opportunity to develop revegetation solutions that focus on landholder needs high in the landscape.

These points made Dongolocking the outstanding area on which to base a remnant vegetation pilot planning project.

Project Objectives

The project objectives are couched at two levels:

i. National objectives towards which the project is expected to contribute; and

ii. Local objectives that guide specific on-ground works to achieve local conservation goals.

National Level

This plan has been written to meet, under contract, goals established by two of the funding agencies - LWRRDC and EA. These agencies have funded a series of research reports aimed at improving conservation of natural biodiversity with a major focus on remnant vegetation protection. The contract objectives provided by these organisations are the overall, broad goals of this project. These objectives are:

i. Assisting government agencies, community and rural industry groups and researchers to develop and test methods for planning and implementing vegetation management at catchment or regional scales;

ii. Encouraging the use and uptake of research results and knowledge, gained from the EA/ LWRRDC national program of R&D into remnant vegetation and from other R&D, to help establish programs of sustainable vegetation management and revegetation that meet the aim of the National Vegetation Initiative (NVI);

iii. Providing a series of documented case studies, with written records of both process and outcomes, that can be used by others in preparing regional vegetation plans, including proposals for NVI funding.

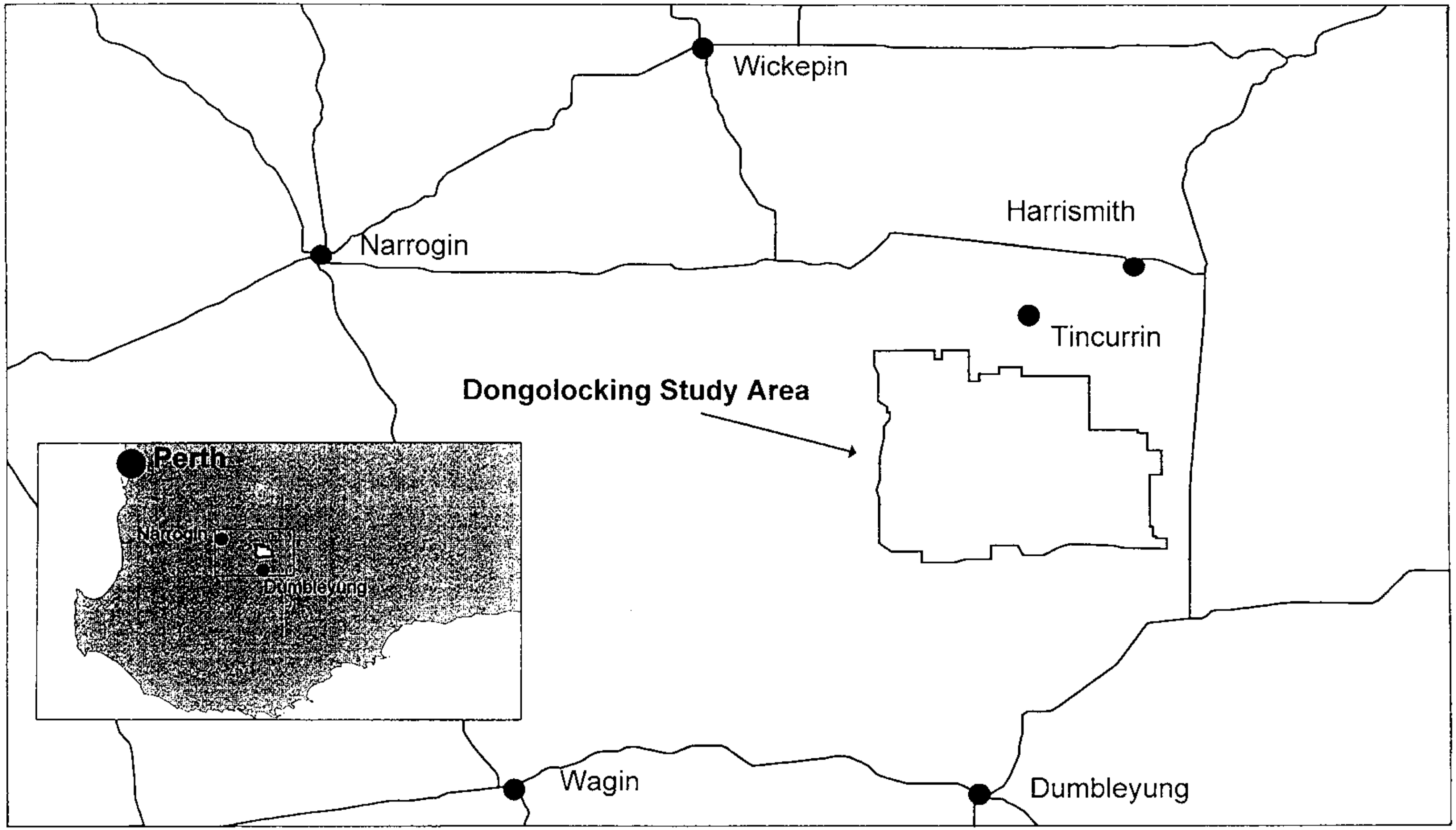
This project is a case study that meets each of these broad goals, particularly (i) and (iii).

Local Level

This project aims to achieve the broad goals listed above by developing a plan for managing remnant vegetation, including revegetation, for the Dongolocking study area. Project members considered six goal options before selecting a specific project goal:

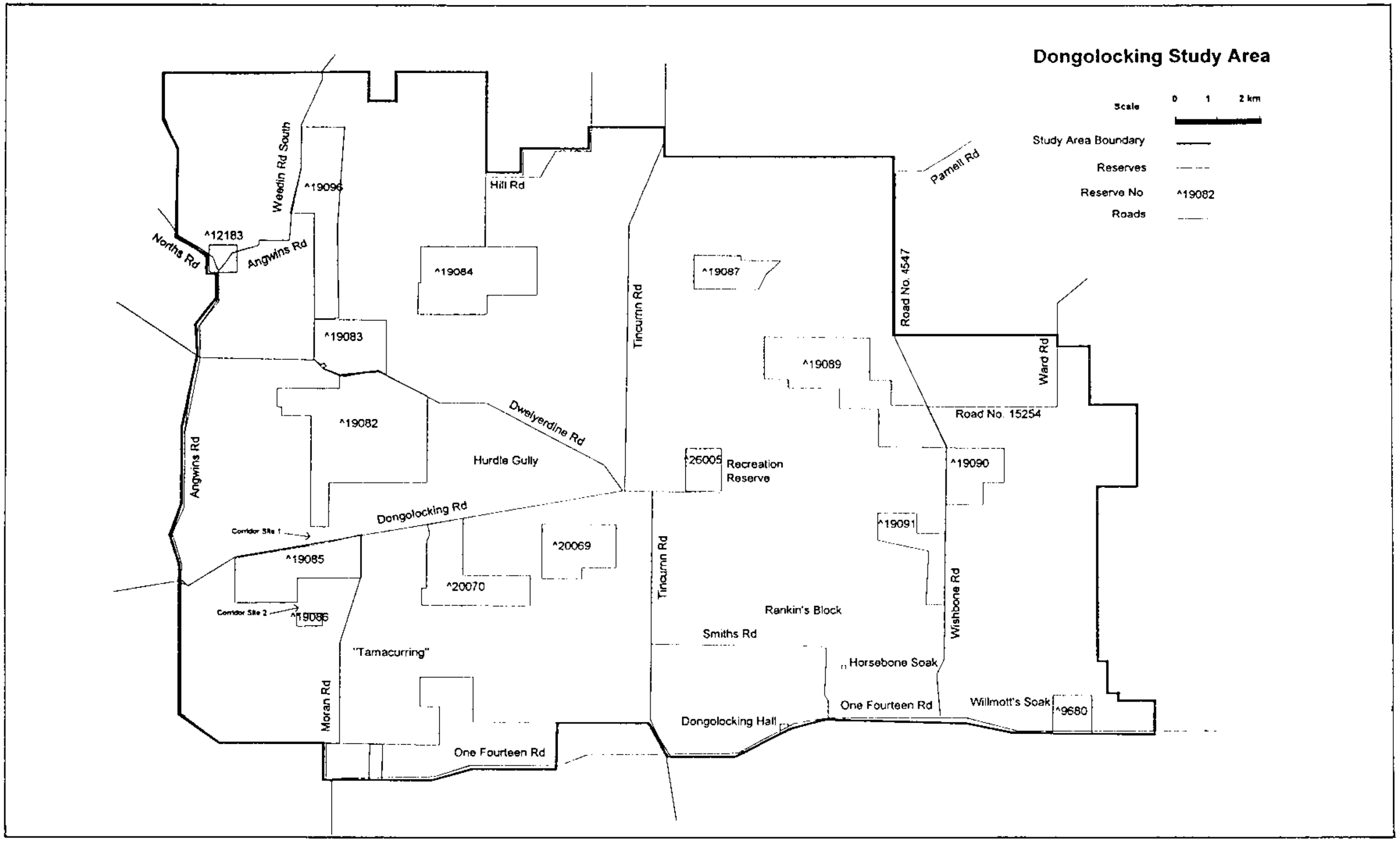
1. Take no positive management action; that is, do nothing. This approach is not acceptable under the national level goals.

2. Ensure that the current threats to nature conservation do not get worse. That is, take action to the extent needed to ensure that new threats to nature conservation are prevented, but don't do anything else. At their simplest, major actions to achieve this goal include:
   - preventing the introduction of new environmental weeds and diseases;
   - preventing further land clearing; and
   - preventing introduction of environmentally damaging animals.



Map 1: Location of Dongolocking study area

Map 2: Dongolocking study area



Given the interest in experimenting with perennial plants and aquaculture, this is a difficult objective. Indeed, this goal has not yet been achieved at any regional level in Australia. While this aim is consistent with national level goals, team members sought a higher level goal.

3. Slow the inevitable decline of biodiversity values in rural landscapes. It is widely accepted that species loss from rural areas is continuing. While actions under (2) will help ensure that the rate of decline is not dramatically increased, they will not slow the rate of decline. To slow the rate of decline will involve a wide range of "general enhancement techniques" that include revegetation and improved remnant management. Actions described in *Managing Your Bushland* (Hussey and Wallace 1993) are required to "slow the inevitable decline", although much of the information in that book would also lead towards the following goals.

   Although community groups implementing management actions often consider they are working towards more effective outcomes, such as goals (4) or (5) below, this is rarely the case. A deeper examination of general remnant management outcomes would reveal that, at best, managers are slowing species decline, and so are generally meeting only goal (3). While goal (3) is a worthy one, particularly at broad scales or where detailed information is unavailable, a more rigorous objective was sought at Dongolocking.

4. Take positive steps to conserve specific elements, generally threatened species or communities. At landscape scales, the shift from goal (3) to (4) is a quantum change. It requires much greater resources, and these must be committed over decades. In Western Australia at least, achieving this goal at landscape and broader scales has never been attempted without government resources. Examples of projects to achieve this goal include management of rare species and work to implement the Toolibin Lake Recovery Plan. Even though goal (4) was regarded as ambitious, it was decided that the next goal could be achieved at Dongolocking.

5. Take positive steps to conserve all natural populations in an area. At Dongolocking, this goal will be difficult to achieve, but not impossible. It was considered by the Steering Committee that Dongolocking is an appropriate area to test whether management can be planned and implemented in rural areas to achieve such a demanding goal.

6. Reconstruct landscapes and their natural biota. Whether species reintroductions should be a component of Dongolocking project goals was considered. While mammal reintroductions may occur during the next fifty years, it was decided that the fundamental objective should be to retain what is currently there. Reintroductions are generally beyond the resources of land managers, and their consideration at Dongolocking would have over-taxed project resources.

   One consequence is that planning vegetation management for future reconstruction is ignored. For example, revegetation actions that will cater for the special habitat needs of a locally extinct species are not planned, and this may affect the potential for reintroduction. This limitation is accepted. It should be noted that current reconstruction in Western Australia only involves threatened species, generally mammals. Furthermore, programs involving the latter are only undertaken on large areas of bushland. The best examples of reconstruction in rural Western Australia are re-introductions of native mammals at Lake Magenta Nature Reserve and Dryandra Woodland under CALM's Western Shield program.

Having decided that a goal consistent with (5) above would be most appropriate for the Dongolocking project, the following specific goal was formulated:

> "To manage the remnant native vegetation and surrounding lands so that populations of the existing native biota are viable in the medium term (fifty years)."

In planning to achieve this goal four constraints are recognised:

a) The goal cannot be achieved in isolation from existing land uses, in particular, farming. Therefore the sustainable, productive capacity of farmland must be enhanced as a result of effectively managing native vegetation and revegetation. This constraint recognises that, in the south-west, the most economic means of achieving biodiversity conservation necessarily involves sustainable land use, and *vice versa*.

b) All ecosystems are dynamic. Over long time periods, extinctions will inevitably occur and even landforms will change. Disease, fire, windstorms and other disturbance events are essential to maintain the space and range of habitats upon which natural biodiversity depends. Even in an uncleared landscape these factors cause local extinctions. In a landscape fragmented by clearing for agriculture the frequency of extinctions is accelerated. It is possible that the introduction of a new disease, or the combined occurrence of several disturbance events (for example, catastrophic fire and a locust plague) will lead to one or more extinctions at Dongolocking within the medium term. However, it has been crudely estimated (see Appendix) that if the management actions planned in phases I and II of this project are implemented, the probability of the threats described in "Threats to Current Land Use" leading to local extinction of any one element of the recorded biota is reduced from 1.0 to less than 0.2.

c) The time frame (fifty years) of the goal is much shorter than the return times of many of the events being managed. For example, habitat hollows essential for some fauna may take up to 140 years to develop and the life cycle of many local tree species exceeds 200 years. In writing management strategies we have aimed to take these long periods into consideration. However, we recognise that our knowledge is inadequate to manage for these longer time scales with much predictability.

d) Some native animals that have been recorded in the Dongolocking district require, to maintain a viable population, an area larger than the study area. These include species with very large area requirements, such as the wedge-tailed eagle (*Aquila audax*), and migratory and nomadic species, such as the rainbow bee-eater (*Merops ornatus*). These species must be managed at a larger scale than the present study area. Indeed, for migratory species, several biological regions may be involved.

Finally, while the development of the project goal has been presented above as a logical, linear process, this is deceptive. Several times during the project, the broader context for decisions was developed retrospectively. This is not desirable, and reflects the general lack of decision-making frameworks. We hope that the framework we have developed here will provide a basis for future, similar work.

"Authority" of this Plan

This plan has no prescriptive power over any land managers, either private or government. Whether suggested works are implemented is entirely at the discretion of the individual landholder or responsible agency.

by Ken J. Wallace

The project has been divided into two phases:

I. Planning for remnant vegetation management at two scales, that of individual remnants and at the scale of the study area. In this phase broad revegetation requirements for nature conservation are developed at the regional scale, but not the farm scale.

II. Development of revegetation and implementation plans in consultation with land managers. These plans will integrate a range of objectives at the local and landscape scales.

Funding has been received to complete phase I only, and it is likely that elements of this phase will necessarily drift into phase II, an issue dealt with in "Implications from Phase 1 of the Dongolocking Work".

Given that phase II has not begun, and funds are not guaranteed, methods discussed in this section mostly refer to phase I. Methods for this phase may be divided into:

- Project management;
- Identifying stakeholders;
- Refining objectives and methods;
- Gathering information and ideas;
- Development of a written plan; and
- Consultation and communication of the draft plan.

Each of these is discussed below.

Project Management

The project is led by CALM which developed, in consultation with other major stakeholders, the project brief. CALM is contracted by LWRRDC to deliver the project outputs. In turn, CALM has sub-contracted parts of the project to CSIRO.

A steering committee was formed to:

- provide liaison between key stakeholders in the project;
- coordinate project development; and
- provide a forum for discussion, generating ideas, and developing solutions to particular issues.

This steering committee consists of (in alphabetical order):

Brett Beecham	CALM
David Bicknell	AgWA
Bruce Bone	CALM
Michelle Brown	Dumbleyung Land Conservation District Committee
Richard Hobbs	CSIRO
Robert Lambeck	CSIRO
Terri Lloyd	Dumbleyung Land Conservation District Committee
Jason Smith	Dumbleyung Land Conservation District Committee
Ken Wallace	CALM, Project Manager and Chair of the Steering Committee

Agencies nominated their representatives, and the Dumbleyung Land Conservation District Committee selected representatives on behalf of local landholders. Due to the short time available for the project, and its coincidence with major farm activities such as seeding and shearing, it has proved difficult to achieve full attendance at each meeting. However, the formation of the steering committee has been of great value in identifying key contacts amongst stakeholders and coordinating activities involving local landholders. It is essential to have local landholder representatives with whom to generate and test ideas, and to provide feedback and help coordinate local meetings.

Identifying Stakeholders

"Stakeholders" in this context include not only local landholders and other land managers, but also those with relevant information, such as the Western Australian Museum. The term also includes those who may affect the implementation of the project (for example, Regional Assessment Panels for the Natural Heritage Trust). Using this broader definition stakeholders are listed over.

Project Stakeholders

*Aboriginal Affairs Department	*National Parks and Nature Conservation Authority
*Agriculture WA (including Agriculture Protection Board)	Nyoongar Council of Elders
*Biospherics Pty Ltd (managing an adaptive environmental project within the Blackwood Catchment)	*Oil Mallee Association
*Blackwood Catchment Coordinating Group	Oil Mallee Company
Cowan, H Hon (MLA)	Pastoralists and Graziers Association
*CSIRO Division of Wildlife and Ecology	Regional Assessment Panels (NHT)
*Department of Conservation and Land Management	Soil and Land Conservation Council
*Department of Environmental Protection	South Toolibin Catchment Group
Department of Land Administration	Southern Aboriginal Corporation
*Dongolocking Catchment Group	State Assessment Panel (NHT)
*Doradine Catchment Group	State Salinity Council
*Dongolocking Corridors Project	Telecom/Optus
*Dumbleyung Land Conservation District Committee	*Tertiary Education Institutions
*Dumbleyung Shire Council	WA Farmers Federation
Emergency Services (particularly Bush Fires Board personnel)	*WA Museum
*Environment Australia	*Wagin Catchment Group
*Farmers in the project area	Wagin Land Conservation District Committee
*Fence Road Catchment Group	*Wagin Shire Council
*Greening Western Australia	*Water and Rivers Commission
Kaata-Wangkinyiny Regional Council	Water Corporation
*Land and Water Resources R&D Corp	*Wickepin Land Conservation District Committee
*Marion Massam, Australian Bird and Bat Banding Scheme	*Wickepin Shire Council
	Wiese, R Hon (MLA)

All those marked with an (*) have either been contacted directly, or members of their groups have been contacted by one or more members of the Steering Committee. Contact has been through one or more of the following methods:

- written information;
- telephone discussions;
- meetings; and
- face-to-face discussions.

An article in the local paper provided broader coverage for the project. It is planned to involve all the listed stakeholders in the project by the end of the planning phase. Naturally enough, work with local land managers, in particular, will intensify during phase II.

Refining Objectives and Methods

Although broad goals and methods were decided during project development, an early task of the Steering Committee was to re-visit the goals and approach. This involved field trips, and a range of group discussions. Also, while local landholders were consulted during the development of the project, broad landholder agreement with the project goals was not established until a public meeting in April 1997. This is not a desirable situation, and if enough time had been available for project development, all local landholders would have been consulted during project development.

When the project goals had been refined, options for meeting them were considered and are discussed in the "Introduction". While it is unlikely that the primary goal will change, it will be re-assessed during the project, and will need to be re-visited during any implementation phase.

During early project development it was agreed that work by CSIRO at Wallatin Creek near Kellerberrin, which had involved landscape scale planning for species retention, should form the basis for the approach at Dongolocking. This provided a technical and knowledge base upon which to build, and did not involve development of alternative methods. Such development work was, in any case, beyond the resources and time available for the project. Nevertheless, applying the CSIRO model to Dongolocking has the merit of testing and further developing an existing model in a new situation.

It is recommended that a project with more time should explore alternative approaches at both a conceptual and technical level. For example, at a conceptual level the value of keystone, trophic level, and other approaches should be considered. At a technical level this project used vegetation as the primary means of classifying habitats. An alternative that could be explored would be to use soil/landform for initial stratification as this may be more sensitive to the distribution and needs of reptiles and amphibians.

Information Gathering and Collation

Information gathering and collation included:

- accessing and collating existing technical data and scientific knowledge;
- rapid surveys to assess the status of potentially vulnerable bird species;
- recording and collating undocumented scientific knowledge;
- interviewing land managers working within the project area; and
- consulting other stakeholders.

Before looking at these in more detail, it is worth mentioning a number of "golden rules" that emerged during the project and apply to all these stages:

a) Make sure all those collaborating in specific aspects of the project have communicated with each other such that they agree on commitments, procedures and data use. Get the agreements in writing, and regularly check timelines.

b) Develop protocols that allow those with information to feel comfortable sharing information with the project.

c) Fully document procedures and verbal information, including adequate minutes for technical meetings.

d) Ensure that no collation, analysis or documentation undertaken during the project has already been done by someone else.

e) Assume that there will be data, software and hardware incompatibilities that will cost time and money. There always will be.

f) Ensure sources are properly acknowledged and copyright approvals are obtained where necessary.

While these are all "common-sense", we have failed in some degree with all except (f) - and there is still time for that!

Accessing and Collating Existing Technical Data and Scientific Knowledge

Accessing data has not been an issue in this project as the published material and relevant unpublished reports, with few exceptions, are captured on a bibliographic data base (Papyrus software) held by CALM. However, we have been unable to access some data from research in progress, as the owners were not willing to release information until the research is complete. Also, resource and communication issues hindered access to some data sets.

Differences in approach by biological survey workers has caused some difficulty in bringing vegetation data together. Also, there is no standard State system for entering floristics and vegetation data into computerised systems. This, together with software issues, slowed progress with some collation and analysis of data.

Recording and Collating Undocumented Scientific Knowledge

Important and relevant data is often held as anecdotal or unpublished information by scientific workers, agency land managers and local landholders. A "scientific experts" workshop was held to test some of the project methodologies and capture anecdotal information held by the scientific community.

Additionally, a member of the Steering Committee interviewed older local residents to capture other important anecdotal information.

Detailing Land Manager Needs

A vital component of the planning process is to understand and incorporate land manager aspirations and needs. Major land managers in the area are local farmers and CALM. Farmers were interviewed and described their thoughts on remnant management and revegetation. The results of this work are described in "Demographics and Needs of Freehold Land Managers".

CALM land managers have participated in the writing of the plan.

Consulting Other Stakeholders

Where necessary, other stakeholders have been contacted with respect to particular issues. For example, the Aboriginal Affairs Department has been consulted concerning the presence of sites that should be taken into consideration during management, and a presentation was given to the Blackwood Catchment Coordinating Group concerning the project.

Development of Written Plan

Sections of the plan were allocated to particular agencies or individuals to draft. This included, where appropriate, analysis, interpretation and manipulation of data. Apart from the contribution by Angas Hopkins and Greg Beeston, all material has been written by members of the Steering Committee. While authorship is acknowledged at the beginning of each section, group discussions were important in the development of ideas.

Consultation and Communication

Sections of the plan have been given to experts for comment. The whole plan will be circulated for comment to members of the steering committee and made available to farmers involved in the project. If the project enters the second phase, then this draft will be revised to take comments into consideration. The second phase of the project would also involve comprehensive consultation with local landholders interested in developing integrated revegetation plans.

During phase I, a field trip was held with local farmers to discuss various management issues and progress with the plan. A similar field trip(s) are proposed for phase II.

Throughout the project, the following techniques have been used to inform local landholders:

- public meeting;
- article in local paper;
- field day;
- direct mailing (including faxes);
- local representatives of the Steering Committee; and
- one-to-one contact, either in person or by telephone (at least once with each landholder).

The Steering Committee proposed to circulate a newsletter, but this has not been sent at the time of writing.

The above steps in the planning process are summarised in Table 1 below.

Table 1: Project development and planning - summary

Core Task	Sub-tasks
Project Development	• someone has an idea and starts talking to people, and a prospective project site and goal are selected. • a group, either formal or informal, is formed. • stakeholders are identified. • endorsement received from stakeholders, or at least sufficient to keep going.
Planning Phase	• form steering committee and decide project manager. • specific goals and a broad approach are decided. • resources to implement planning are sought and gained. • existence of the project is communicated to all stakeholders. • information gathering, collation. • revisit goals and approach (this will probably have to be done several times through the life of the project). • write plan. • communicate, discuss plan. • re-write plan. • disseminate plan.
Implementation Phase	• role of steering committee has now changed; assess whether such a committee is needed, and if so, what form it should take. It is likely that the implementation may be handled by existing groups. If not, it is probable that the implementation committee will be quite different from the planning committee in structure and function. • seek resources for implementation. • monitor and review implementation. • review and rewrite plan to take into consideration new information, ideas and circumstances.

LAND MANAGEMENT AT THE LANDSCAPE SCALE — A FRAMEWORK

by Ken J. Wallace

Landscape planning and management may be approached in numerous ways and at a range of scales. At Dongolocking, a simple framework and planning process were used to provide a context within which to work. These are described below.

Landscape Planning Framework

Landscape components that must be integrated in landscape planning are outlined in Figure 1 (page 12). In this table, the separation of the agricultural environment into living and non-living components and their various elements is a "text-book" approach except for two important features.

Firstly, cultural structures - such as roads, railways, buildings, fences, etc. - are particularly important in agricultural environments as they have significant effects on the movement of both living things (for example, roads as barriers to invertebrate movement) and non-living elements such as water. Therefore, cultural structures may be an important focus in some forms of landscape planning.

Secondly, biotic components in the table are separated into human needs and non-human elements. This division emphasises that the agricultural environment is largely a cultural landscape, at least in the management timeframes considered at Dongolocking. In this context the expression of human needs will have a profound impact on the environment, and their management is the key to effective planning.

In the Dongolocking project, human needs are expressed through four demands on the project area:

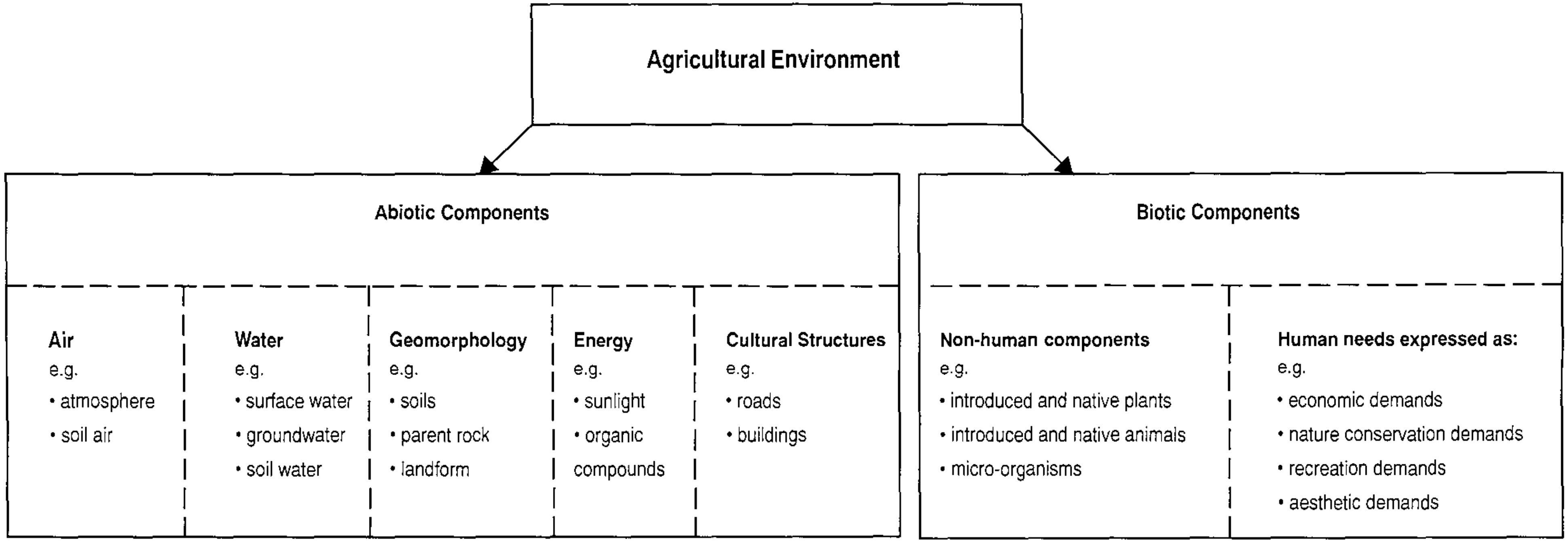
- economic needs, particularly as expressed through agriculture;
- nature conservation aims, which are largely an expression of the desires of the community outside the Dongolocking area, although they are also stated by those living within the study area in various forms (see "Demographics and Needs of Freehold Land Managers");
- 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 it is convenient to use these readily identified needs as the goals for landscape planning, and in particular, the first two, it should be recognised that they in turn reflect more fundamental human needs that are usually some variation of the following list:

- food and water;
- shelter;
- minimal physical threats;
- companionship;
- successful reproduction;
- spiritual/philosophical well-being;
- physical and mental health;
- meaningful occupation; and
- some level of luxuries.

While discussion of these is beyond the scope of this report, managers must remember that these needs are more fundamental, and may underlie seemingly incongruous decisions. For example, while they are uncommon, there are some people who believe that bush should be "civilised" by bringing it into production - reflecting a fundamentally spiritual view. Nature conservation and its usual justifications will have little appeal to such a person. Other examples include farm management decisions made for reasons of meaningful occupation or companionship (peer group) rather than economics. While it is beyond the capacity of most landscape planning projects to delve to this level, its impact on decisions should not be under-rated.

Ultimately, if the relevant human needs are not met by those with influence over implementation of the landscape plan, then it will almost certainly fail. For this reason, both the landholder surveys and the planning by landholders (phase II) are vital to the project's success. A complicating feature is that not only must the needs of those within the project area be met, but also those outside. This includes, for example, downstream landholders, conservation groups and funding bodies.



Interactions between the above components, including dynamic and temporal aspects, are described through environmental processes.

Of particular relevance in agricultural environments are the:

- water cycle;
- nutrient cycle;
- energy cycle; and
- oxygen cycles.

Note: Other processes are "sub-processes" of these cycles. For example, predation is part of nutrient and energy cycles, erosion part of energy and water, climate part of energy and water, and so on.

Figure 1: Landscape planning components - agricultural environment

Landholder surveys, and descriptions of soils, vegetation, etc., were used in this project to document the most important environmental components.

As shown in Figure 1 (page 12), interactions between environmental components, including dynamic and temporal aspects, are described through environmental processes. Of particular relevance in agricultural environments are the:

- water cycle;
- energy cycle;
- nutrient cycle; and
- oxygen cycle.

The importance and operation of some of these cycles are well described for the wheatbelt in the work of Main (1993), Lefroy *et al.* (1993) and other papers in Hobbs and Saunders (1993). Other important processes, such as disturbance, predation and meteorological cycles - are "sub-processes". For example, predation is a part of both the nutrient and energy cycles, and weather reflects the interplay of water and energy cycles within any given environment.

Where processes and cycles operate in a way that endanger a land use goal, this is expressed as a threat. For example, threats to a range of land uses posed by increasing surface soil salinity and waterlogging reflect perturbations in the hydrological cycle, and fox predation threats to fauna signal changes in nutrient/energy cycles. In this project, existing and potential threats along with management responses are documented as a means of accounting for environmental cycles and processes. The probability of threats affecting achievement of the project goal (see Appendix) provides a measure of which threats should be dealt with as a matter of priority.

The components and environmental processes described above and in Figure 1 (page 12) provide the framework for landscape planning at Dongolocking. This framework will be further developed during phase II of the project.

Landscape Planning Process

The landscape planning process being used at Dongolocking is described in Table 2 (page 14). This table is largely self-explanatory, however, tasks (1) and (4) need further explanation.

Project Goal (Task 1)

As with all management work, it is imperative to have a clear goal or goals (task 1) to drive planning and action. While the primary goal of this project is expressed in terms of nature conservation, it was also stressed (see "Introduction") that "the sustainable, productive capacity of farmland must be enhanced as a result of effectively managing native vegetation and revegetation". Therefore, at the landscape scale, a secondary project objective is enhancing agricultural productivity and sustainability. As the current hydrological imbalance threatens both these aims, integration at the landscape scale at Dongolocking is focused - with respect to remnant protection and revegetation - on:

- nature conservation;
- enhancing productive capacity and sustainability of farmland; and
- increasing local water use to combat salinity and water-logging.

Each of these will be specifically treated during the project; the first during this phase (see page 17), and the last two during phase II.

Selecting Priority Planning Goal (Task 4)

With respect to task (4), selecting a goal as the basis for landscape planning, there are two reasons for selecting nature conservation as the foundation for planning.

Firstly, it was decided that the goal which is most complex and ecologically demanding should provide the initial foundation for landscape planning. Nature conservation goals are appropriate because those for either hydrological purposes or enhancement of sustainable, productive agriculture, may be met in comparatively "simple" ways. For example, planting a perennial plant monoculture that is economically valuable may meet the latter goals, but will not meet nature conservation aims.

Secondly, while it is theoretically possible, with enormous resources, to achieve nature conservation independently of other land use goals,

Table 2: Landscape planning tasks and Dongolocking approach

Landscape Planning Tasks	Approach Taken at Dongolocking	Potential Improvements to Approach
1. Determine Goals	To manage study area lands so that populations of the existing native biota are viable in the medium term. Given that sustainable agriculture is vital to achieve this, it is also a goal at the landscape scale.	Greater detail could be provided for non-biodiversity goals. However this, including planning, would have required much greater resources (time and money) than were available.
2. Document components of environment that significantly interact with management goals.	Flora, fauna, soils, land use, landholder and conservation needs, distribution of remnants, and so on were documented.	If greater resources had been available, needs of the wider community would be more fully documented.
3. Document relevant processes, interactions and management responses.	These are encapsulated in the list of threats (which reflect process issues), and the Appendix which deals with probabilities. This, particularly if further developed, would provide information on most important process issues over the next 50 years.	Process issues operate over timescales greater than the 50 years selected for the project. Also, resources could be allocated to deal with the threats to other land uses, however, these were not the primary goals.
4. Select the project goal(s) that are most ecologically complex and demanding to implement, and use this as the basis for the first "cut" at planning. (Could use most demanding human need.)	Biodiversity conservation is most ecologically complex and demanding (as reflected in the management goal). Habitat component seen as primary issue, management response determined through focal species planning.	Other aspects of biodiversity conservation could be dealt with in the same detail as habitat. However, most of these will be dealt with in the section on managing individual remnants (Phase II of the project).
5. Plan for other goals and integrate them with primary goal. This may involve significant addition or amendment to primary goal.	Phase II of project.	To be assessed during Phase II of the project.

this will never be culturally acceptable in agricultural areas of south-west Western Australia. Thus many threats to nature conservation may only be countered by achieving sustainable land use in a way that is sympathetic to nature conservation.

Whether the corollary is true, that the best way to achieve sustainable land use involves conserving natural diversity, is still debated and not broadly accepted within the rural culture. Therefore, if nature conservation is a goal, not to have it as the primary goal may lead to it being ignored, or at least treated at a very general level. However, given that nature conservation is dependent on some form of sustainable agriculture, there is no avenue for ignoring the latter goal.

In summary, the challenge in agricultural regions is to manage human values, as expressed through actions, in a way that delivers sustainable land use and supports an acceptable quality of life now and in the future. This is not simply a task of managing environmental components of the study area - environmental factors and human values from outside the study area have an enormous influence on events at Dongolocking.

NATURE CONSERVATION AT THE LANDSCAPE SCALE – A FRAMEWORK

by Ken J. Wallace and Brett C. Beecham

Background

In the previous section a framework and process were described for planning management at a landscape scale. An important part of this framework is the integration of human "demands" at the landscape scale. At Dongolocking, the main demands relate to:

- nature conservation;
- agricultural economics;
- aesthetics; and
- recreation.

In this section, the framework provided previously is extended to cover aspects of planning for nature conservation at landscape scales. The new process is described by Figure 2 (page 18).

This process is considered over a 150 year period, of which 100 years approximates the European history of the study area, and 50 years represents the planning horizon. The current biota has arisen over about 100 years as a result of interaction between a range of threats acting on the biota existing prior to European settlement. Major threats that have, or are most likely to cause extinctions <u>within the study area</u> include:

- land clearing;
- introduction of exotic predators and herbivores;
- broadscale disturbance, particularly fire;
- environmental weeds;
- salinity;
- disease, particularly *Phytophthora* spp if introduced; and
- the low values placed by people on native plants, animals, and their habitats.

A much more detailed description of threats is given in "Threats to Current Land Use".

While it is possible that changes would have occurred in the natural biota if European settlement had not occurred, change brought about by humans has been so overwhelming that natural variation and losses have been masked or insignificant in comparison. Over the next fifty years further changes in the biota may occur depending on how threats are managed.

The aim in this project is to manage threats caused by humans in a way that ensures the Dongolocking biota persists (with a 0.8 probability) for 50 years. This goal is explained in more detail on pages 2-6.

Until the 1970s there was little management of natural areas at Dongolocking for conservation. Over the last 25 years there has been increasing management, both of Crown and freehold lands. However, continuing with current management strategies alone is unlikely to prevent extinctions occurring over the next 50 years. There is a need to increase management. To achieve the objective of the Dongolocking Project, action is required at a landscape scale.

Management at A Landscape Scale

Management for nature conservation at a landscape scale generally involves:

- provision of adequate habitat patches to maintain viable local populations;
- provision for recolonisation;
- direct management of threats; and
- management of particular species (usually threatened or commercial) and communities.

Each of these is considered below.

Provision of Adequate Habitat Patches

If the effects of threats, apart from past land clearing, were to have no greater impacts in the future than they do at present, then the only management required at a landscape scale would be to ensure that habitat patches were sufficiently large, or sufficiently well connected, to maintain viable populations of each species. If adequate habitat is provided by increasing the effective size of current remnants and creating better connections, then this should prevent further loss of species due to insufficient resources to support viable populations. The provision of adequate habitat patches is a major focus of this project, and is discussed in detail in "Nature Conservation at the Landscape Scale - Adequacy of Habitat".

However, the intensity of other threats is not stable. For example, the effects of salinity and weed invasion will worsen. Therefore it is not enough to

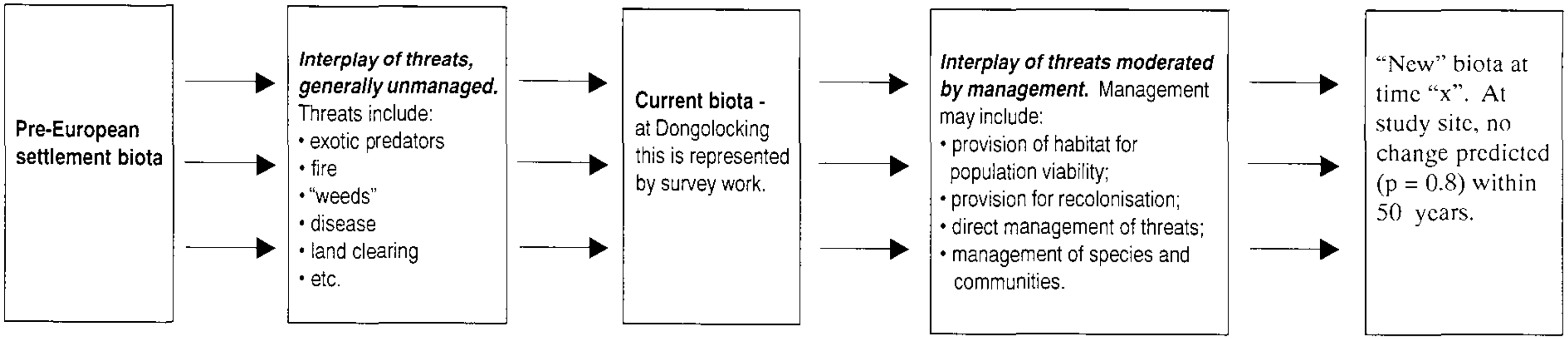


Figure 2: A Framework for nature conservation at the landscape scale

simply increase habitat to an "adequate" level; three further types of management are necessary at the landscape scale.

Provision for Recolonisation

A catastrophic event, such as a very large wildfire, may cause the local extinction of a species that would otherwise be considered viable. Provided the affected area is sufficiently well connected to viable populations within or outside the study area, recolonisation should occur. At Dongolocking the study area is probably large enough, with adequate management, to ensure viable populations are available for recolonisation of disturbed areas from within the study area, provided connections are established where necessary. Corridors proposed in "Nature Conservation at the Landscape Scale - Adequacy of Habitat"should meet this purpose, at least for birds. However, the connection of the study area at an even broader scale to areas outside the study area is important to ensure recolonisation after extreme disturbance events. This very important aspect of recolonisation will be considered in future developments of this project.

Direct Management of Threats

Many threats may be managed directly. For example, fox predation has caused the decline of many animal populations. While it is possible to manage individual species or remnants for fox predation, to meet the conservation objectives at Dongolocking it is important that fox control occurs throughout the study area. Similarly, weeds, fire and other threats require strategic management at both the landscape and smaller scales. Some of these issues are covered further in the section "Nature Conservation at the Landscape Scale - Other Factors". Management of threats at the scale of individual remnants is covered in "Nature Conservation at the Remnant Scale".

Management of Species/Communities

Effective management of threatened species and commercial species (for example, the western grey kangaroo) requires action at scales ranging from individual populations to the national level. In the case of Dongolocking, management of these species is covered under published or draft CALM plans. Reference should be made to these for further information - these topics are not dealt with in this project.

Management of threatened communities is a developing area. While there are undoubtedly threatened communities at Dongolocking, a good case can be made that they are all threatened. It is also possible that there are communities and associations at Dongolocking that are particularly important in relation to key environmental processes. However, until these concepts are better developed, they are not amenable to management. (An obvious exception close to Dongolocking is the Toolibin Lake Recovery Plan and its implementation.)

Scales at which Management Actions Are Applied

It is apparent from the above discussion that management strategies and actions may be applied at a range of scales that reflect areal extent. These scales may be usefully separated into:

- individuals;
- populations;
- specific, identifiable areas of bushland;
- landscapes; and
- bioregions and larger scales.

These scales have been selected to represent identifiable, discrete physical areas. While species and communities have been used by some workers as scale entities, they reflect scales of organisational complexity rather than areal extent. They are therefore used in this report as categories of management (threatened species and communities and commercial species, see above) rather than as scales of management. Each of the scale levels is briefly considered below.

Individuals

Where conservation of genotypes is an issue, management may be necessary at the level of individuals of a species. At Dongolocking this is most likely to arise in the case of either threatened species - for example, there is provision for protection of hybrids and sub-species - or plants and animals of high commercial value. Neither of these is a planning focus of this project.

Populations

The management of individual populations is most likely to occur in relation to threatened species and the protection of commercially important species. Again, this is not a planning focus of this work, and is covered in draft or completed CALM management plans. However, it is noted that operational management of populations is necessary to meet landscape scale objectives.

Specific Areas of Bushland

In the agricultural zone, native vegetation generally exists only as discrete remnants. Individual remnants have been a common focus of management action and planning, and this is specifically discussed in "Nature Conservation at the Remnant Scale". Very large remnants (especially those larger than 50 000 ha) will spill into the next level of management given that they include numerous landforms and may constitute a landscape unit.

Landscapes

With respect to nature conservation in the agricultural zone, this level generally involves managing a group of remnants and their matrix as a unit. An essential element of this approach is that sustainable management of the (generally) agricultural matrix within which the remnants are embedded must be at least neutral, and preferably sympathetic, to conservation goals. This approach forms the primary thrust of planning work at Dongolocking.

Bioregions and Larger Scales

This group could be separated into a range of components including bioregional, state, national and global scales. These scales are beyond the scope of the present work. However, it is noted that they are important scales for particular forms of planning. For example, many migratory species cross bioregional, state and national boundaries. Effective management of some migratory waders occurs at multi-national scales. These broader scales are also an important context within which policy and resource arrangements are developed.

In contrast, these scales are rarely effective for planning on-ground implementation (see the discussion under "Goals and Scale", page 93), and are not developed in this project.

Action Planning for Dongolocking

Apart from the sections "Works Required to Complete Plan" and "Implications from Phase 1 of the Dongolocking Work", the remainder of this report details what has been achieved in following the framework proposed here and in the previous section. Table 3 summarises the relationships.

Table 3: Report sections and relationship to landscape framework

Title of Chapter	Relationship to Framework
• Description of the Study Area. • History of the Dongolocking Study Area. • Demographics and Needs of Freehold Land Managers.	These three sections describe relevant aspects of the biotic and abiotic environment at Dongolocking, and its recent history.
• Threats to Current Land Use.	The threats described in this section reflect functional and process aspects of the Dongolocking environment that require management intervention to achieve the project goal.
• Nature Conservation at the Landscape Scale - Adequacy of Habitat. • Nature Conservation at the Landscape Scale - Other Factors. • Nature Conservation at the Remnant Scale.	These three sections provide the planning background and broad management actions required to achieve the nature conservation goal.

DESCRIPTION OF THE STUDY AREA

by Brett C. Beecham, Angas J.M. Hopkins, Greg R. Beeston and Robert J. Lambeck

This section provides a biophysical description of the study area under the following headings:

- Geomorphology and Soils;
- Vegetation and Floristics; and
- Fauna.

Sources of information are cited in each section, and these provide an important bibliographic resource outside the computerised system held at CALM offices in the Wheatbelt Region.

Geomorphology and Soils

Geomorphology

The Dongolocking study area lies within the Yilgarn Block, an ancient craton of Archaean granitic rocks approximately 2 500 to 2 900 million years old that have been heavily metamorphosed in places. The earliest event to shape the current landscape was an ice age during the Permian Period, about 270 million years ago (mya). This created a landscape extensively worn down and leveled, with no organised drainage (Beard 1990). A drainage network developed over the subsequent geological periods. By the early Tertiary the landscape had been extensively weathered and eroded.

During the late Cretaceous and early Tertiary Period (70 to 25 mya) the climate was probably tropical, with marked wet and dry seasons and a high rainfall. The combination of wet and dry seasons, and a fluctuating watertable level, led to deep weathering of rocks, and leaching of most soluble nutrients. This left a "pallid zone" of quartz grains, oxides of aluminium and iron, and kaolinite up to 50m deep (Beard 1990).

As the climate became increasingly drier and warmer during the late Tertiary (20 mya), the surface layer rich in iron and aluminium oxides was exposed to the increasingly hot sun. This led to the formation of a hard laterite layer on the surface known as a duricrust. Where the duricrust (or ironstone) comprised nodules (pisoliths) of quartz, iron oxide, alumina and clay, these cemented together to form pea ironstone or pisolite. Where pisoliths did not occur, these minerals formed a solid rock-like layer (massive laterite) (Beard 1990).

There is debate as to whether this surface laterisation occurred uniformly across a peneplain or undulating landscape. Bettenay (1984) suggests that the presence of extensive pallid zones beneath both uplands and valley floors probably indicates that the landscape was gently undulating at the time of laterisation, and has not been substantially modified by erosion since the Oligocene (45 to 25 mya). Erosion has also exposed granite inselbergs and boulder outcrops across the study area.

More recently, extensive sandplains have developed high in the landscape above much of the remaining laterite crust. These sands are derived from locally weathered material that has been reworked or transported by the wind (Bettenay 1984). They are usually absent from the edge of the duricrust where it forms a breakaway, but increase in depth further downslope (Beard 1990).

The study area lies within the upper catchment of the Blackwood River. This is within the Zone of Ancient Drainage so named because it contains the remnants of palaeodrainage systems of the late Cretaceous and Tertiary (Hopper *et al.* 1996). These systems are now reduced to several series of salt lakes that only flow in years of above average rainfall (Tille and Percy 1995). The landscape of the Zone of Ancient Drainage consists of a gently undulating plateau with an elevation between 280 and 400 m. Local topographic relief is generally less than 50 m (Tille and Percy 1995).

The Meckering Line forms the boundary between the Zone of Ancient Drainage to the east and the Zone of Rejuvenated Drainage to the west. The Meckering Line lies slightly to the west of the study area.

Within the Zone of Rejuvenated Drainage, drainage lines are clearly defined and carry water every year (Tille and Percy 1995). The terrain is undulating to rolling, between 240 and 380 m in elevation. Increased dissection of the lateritic profile has lead to a landscape of low rounded hills, often capped by lateritic remnants with breakaways.

The study area lies on the highest part of the divide between the Coblinine and Arthur River sub-catchments. The majority of this area is over 350 m above sea level, with the highest point being 424 m in the west of the study area. The landscape contains numerous laterite capped hills bordered by steep breakaways up to 10 m in height. The remainder of the area is broadly undulating. The upper tributaries of the Coblinine system form a broad valley floor in the south-eastern corner of the study area. This area is generally below 300 m above sea level, with the lowest point being 286 m.

Soils

The four soil landscape systems that occur within the study area are the:

- Tincurrin System, covering only a very small area in the northern edge of the study area;
- Coblinine System, occupying a small portion of the south-eastern corner and a narrow tongue extending north into the centre;
- Kukerin System, occurring in a narrow band along the eastern boundary; and
- Dongolocking System, occupying the majority of the study area.

The following descriptions are taken from Tille and Percy (1995):

Tincurrin System: The Tincurrin System consists of gently undulating rises with shallow duplex soils, sandy gravels and yellow-brown sands.

Coblinine System: The Coblinine System covers the broad, level to very gently sloping alluvial plain of the Coblinine and its tributaries, including Dongolocking Creek. The soils are mainly shallow and deep sandy duplex with grey or brown clay subsoils which are sodic and calcareous. At least 50 percent of these soils are affected by secondary salinity with much of the remainder at high risk of salinisation and waterlogging. Minor soils include cracking clays and calcareous loams.

Dongolocking System: The Dongolocking System has gently undulating to undulating rises with sandy gravels on the crests and upper slopes, sometimes associated with small areas of deep loose white or grey sand. Shallow sandy duplex soils dominate the hill slopes. These soils have sodic brown or grey subsoils and are usually calcareous.

The Dongolocking System also includes shallow sandy duplex soils and small areas of deep coarse sand formed on weathered granite or gneiss and reddish-brown shallow sandy duplex or loamy duplex soils formed on weathered dolerite. Calcareous sodic shallow sandy duplex soils commonly affected by secondary salinisation occur on valley floors.

Kukerin System: The Kukerin System has gently undulating to undulating rises with sandy gravel and loose white or grey sands on the upper slopes and crests. Shallow sandy duplex soils with calcareous sodic subsoils are found on the hill slopes.

Calcareous grey or brown loams are common on the rises immediately adjacent to the alluvial plain on Dongolocking Creek (Coblinine System). The system includes valley flats and areas of deep sandy duplex soils formed on weathered granite.

Representation of Soil Systems in Nature Reserves

Elements of each of the Landscape Systems are represented within the reserve network in the study area. Soil descriptions are taken from Soil and Landscape Map Katanning Sheet 2, 1:150 000, Agriculture Western Australia.

Tincurrin System (Tc): An unsurveyed unit with a small occurrence on the northern margin of the study area. It is not represented within any reserves in the study area. The soils are grey shallow duplex soils, sandy gravels and yellow sandy earths.

Coblinine System (Cb1): Reserves 26005 and 9680 lie predominantly within this System, and are the only representations within the study area. These are saline wet soils with significant areas of alkaline sandy shallow duplex soils.

Kukerin System (Kk1): Small areas of this System occur on the eastern margins of Reserves 19089 and 19090. These are mid and upper slopes, summits and hillcrests of moderately deep sandy gravels with minor areas of deep sandy gravels and pale deep sands.

Kukerin System (Kk1s): Small areas of this System occur on the eastern margins of Reserves 19087 and 19089. These are mid and upper slopes of pale deep sands.

Kukerin System (Kk2): A small area of this System occurs along the eastern edge of the study area, with a minor occurrence in Reserve 9680.

These are lower to upper slopes of grey shallow to deep sandy duplex soils.

Dongolocking System (Do1): This System is widely represented, and has significant occurrences within Reserves 19082, 19083, 19084, 19085, 19087, 19089, 19091, 19096, 20069, 20070, 26005. These are mid and upper slopes, hillcrests and breakaways, with sandy gravels and minor areas of pale deep sands.

Dongolocking System (Do2): This System is also widely represented, and occurs around the periphery of all Reserves except 19083, 19086 and 9680. These are lower to upper slopes, hillcrests and breakaways of grey deep sandy duplex soils with minor areas of grey shallow sandy duplex soils, alkaline grey shallow sandy and loamy duplex soils.

Dongolocking System (Do3): This System is best represented in the western part of the study area, and occurs extensively in Reserves 19082, 19083 and 20070. Smaller areas occur in Reserves 19084 and 19089. These are mid and upper slopes and hillcrests with grey deep sandy duplex soils with minor areas of red sandy and loamy duplex soils, red calcareous loamy earths and granite or dolerite outcrops.

Dongolocking System (Do4): This System is uncommon within the study area, and only a small area occurs within Reserve 26005. These are valley flats and narrow plains, with saline wet soils and minor areas of grey deep sandy duplex soils, including soils with alkaline subsoils.

Soils of the study area are shown in Map 3 (page 24).

Vegetation and Floristics

Vegetation Classification

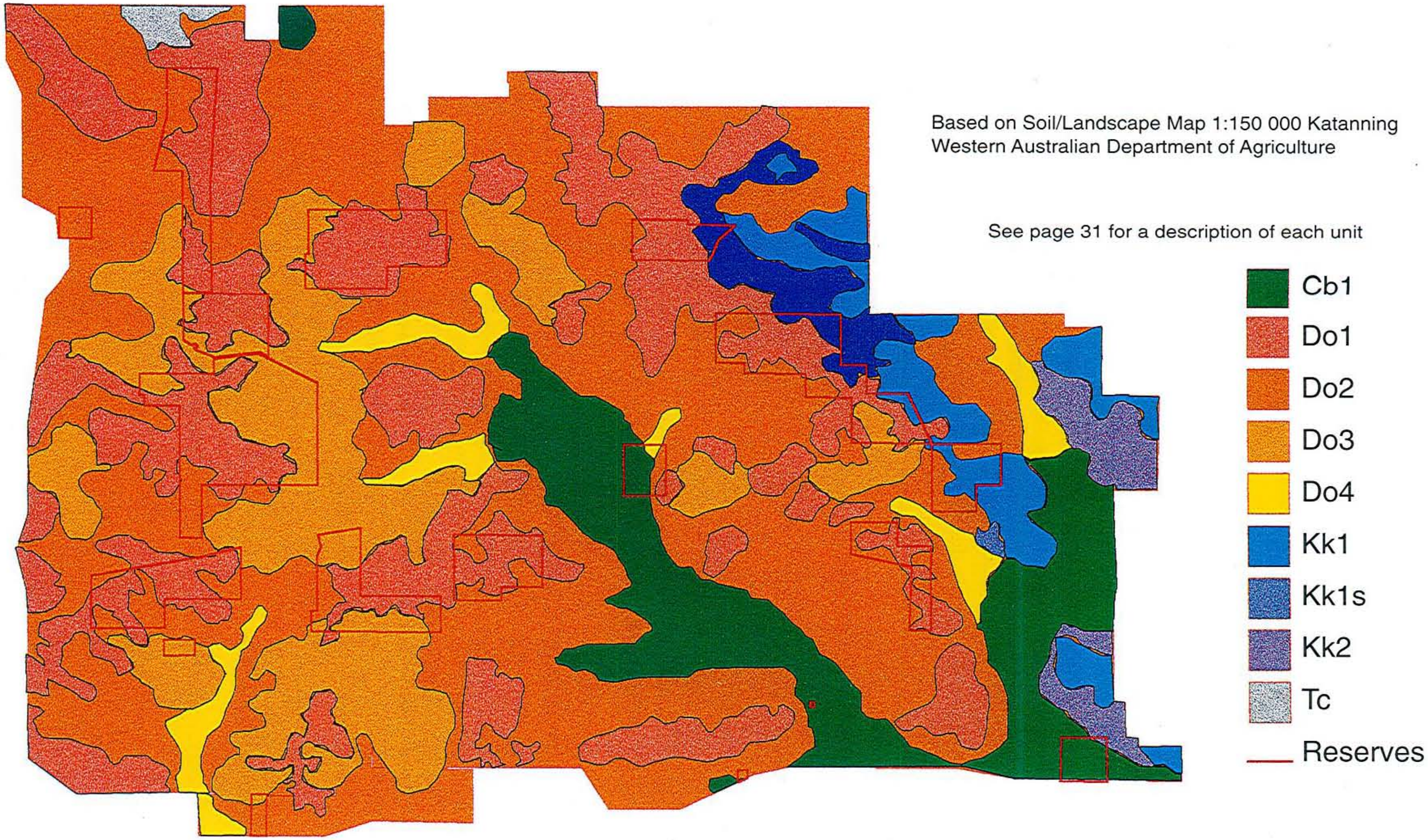
The vegetation of Western Australia is divided into Botanical Provinces, or natural ecological regions. Each Province is further divided into Botanical Districts based upon combinations of climate, geology, landforms, soils and vegetation (Beard 1990). These are in turn divided into Vegetation Systems, defined in Beard (1980) as consisting "of a particular series of plant communities recurring in a catenary sequence or mosaic pattern linked to topographic, pedological and/or geological features".

The study area lies entirely within the Dumbleyung Vegetation System, Avon Botanical District, South Western Botanical Province. The landscape is gently undulating with scattered residual laterite capping and granite outcrops. The vegetation generally follows the catena, with:

- *Dryandra* spp dominated heathland on the laterite residuals, brown sandy loams and on grey and white sands over laterite;
- Woodlands of various mallet species such as brown mallet (*Eucalyptus astringens*), silver mallet (*E. argyphaea*) and blue mallet (*E. gardneri*) on weathered laterite and wash zones below breakaways;
- Shrublands occur on light grey sands, while mallee including *E. eremophila* and *E. redunca* occur on the sandy clays of light colour and on soils with more clay than heath soils;
- Woodlands of wandoo (*E. wandoo*), York gum (*E. loxophleba*), morrel (*E. longicornis*) and salmon gum (*E. salmonophloia*) dominate the undulating country on pallid zone clays;
- Scattered patches of mallee, teatree (*Melaleuca* spp.) and samphire on salt-flats;
- Scrub heath and low woodland on low-level sandplains; and
- Lithic complexes occur on isolated granite boulder outcrops throughout the landscape.

The south-eastern corner of the study area lies near the boundary separating the Avon from the Roe Botanical District (Hyden Vegetation System). The Roe Botanical District is characterised by the dominance of mallee vegetation. Several mallee eucalypts characteristic of the mallee region occur in this part of the study area (Backshall 1985).

The Interim Biogeographic Regionalisation for Australia (IBRA) divided Australia into 80 biogeographic regions representing major terrestrial ecosystems. The study area lies within the Avon Wheatbelt Region. The Avon Wheatbelt Region occupies an area of 94 100 km^2, of which 88% has been cleared of native vegetation, and only 0.5% is protected in nature conservation reserves (State of the Environment Advisory Council 1996). The boundary between the Avon Wheatbelt and Mallee Regions lies about 5 km to the east of the study area.



Map 3: Soil-landscape units within the study area

Pre-European Vegetation

The Dongolocking study area contains patches of remnant native vegetation which cover about 18 % of the landscape. Major areas, now the Dongolocking Nature Reserve, are located predominantly on the uplands - areas between 370 and 420 m in elevation and mapped as the Dongolocking System (Do1) and the Kukerin System (Kk1). There are a few, usually small, patches low in the landscape. It is difficult, therefore, to gain an image of what the landscape may have looked like, and how the various vegetation types may have been distributed, prior to the extensive clearing for agriculture.

To plan an effective landscape management program, which may include revegetation, it is desirable to know some or all of the following:

- What vegetation types were there originally, what was the plant species composition of each vegetation type, and how variable was it floristically?
- Which plant species are most important from a land rehabilitation perspective or from a biological conservation perspective? and
- Will those species still grow where they grew prior to clearing and farming or, are the habitats so severely altered that they will no longer grow?

It is useful, too, to have a picture of how the patches of native vegetation that remain were linked so that, if necessary, similar links may be reconstructed.

The work that is reported here was an attempt to piece together the existing fragments of information about what the landscape looked like prior to clearing and farming, to provide a framework for studies of bird habitat usage and for planning revegetation.

Four sources of vegetation map data of very different qualities were used:

- Detailed contemporary vegetation mapping of parts of the study area (Backshall 1985, Mattiske 1996, Muir 1978, Napier 1986, and Napier *et al.*. 1986). These maps were prepared by air-photograph interpretation with considerable on-ground sampling, with a high reliability. Most mapping was at a scale of about 1:25 000. However, the vegetation units described were not consistent from one study to the next, so considerable attention was given in this study to fitting the 100 or so vegetation associations into a simpler system;
- Sketch maps of bird habitat types produced by Drs Robert Lambeck and Peter Cale during their field work (see "Nature Conservation at the Landscape Scale - Adequacy of Habitat");
- So called Mallet Maps dating from about 1930 were available for 10 locations - areas that had been set aside at that time for the production of mallet bark for use in the leather tanning industry. These Mallet Maps were produced by on-ground survey alone, with a focus on the extent of distribution of the three mallet bark producing species, and with little detail on other vegetation types;
- Sketches prepared by land surveyors over the period 1910-1938. These sketches formed part of the assessment (for agricultural potential) and valuation of each parcel of land prior to its release for agricultural use. Sketches showed distribution of up to three classes of land (that is, first class through to third class), and the accompanying notes provided a brief description of each class of land on that block. For example, Williams Location 10233 mainly 2nd class land with sandy loam, clay sub-soil with salmon gum, jam, mallee, morrel, with some 3rd class land with sandy and gravelly soil with low scrub. Sketches were available for 77 individual locations in the study area.

The linework from these different sources was captured in a Geographic Information System and co-registered on the standard cadastral map base derived from Agricultural Property And Client System (AGPACS). Each unit defined by the linework was then classified into one of nine basic vegetation types (see below), and the redundant linework was deleted. The simplified linework was then overlaid on the soil landscape map data (Map 3, page 24) and drainage line data. The simplified vegetation linework was then extended from the known locations to cover the whole study area by interpolation and extrapolation, to produce a final map.

The nine vegetation types were decided on after viewing the range of data available, and to meet the requirements of the bird survey and subsequent data analysis (see "Nature Conservation at the Landscape Scale - Adequacy of Habitat"). The GIS capabilities were used for a variety of analyses, including intersections and area calculations.

A map of the probable natural vegetation of the 500 km^2 encompassing the study area at Dongolocking in the central wheatbelt of Western Australia is given in Map 4 (page 27). The map shows York gum and jam woodland along the margins of the drainage lines with some unusual patches higher in the landscape. The broad valley bottoms support mainly salmon gum and morrel woodland, but this vegetation type extends onto the lateritic uplands in places. The remaining areas of the uplands support mallet forest and woodlands, mallee, shrublands and heathlands. Areas where it was known that there were massive exposures of granite, or granite boulders, with shallow, coarse sandy soils, and which supported mainly rock sheoak (*Allocasuarina huegeliana*), were mapped as lithic complex.

In this study we have drawn together a range of disparate data sets on the vegetation of the Dongolocking study area to develop a map of pre-European vegetation. The map provides a framework for further work in the area, including research and planning and on-ground work such as revegetation.

The map was prepared as a desktop study, without the authors having the chance to validate any of the work by on-ground survey. The map should, therefore, be regarded as a first iteration. We would recommend that, before revegetation plans are finalised, the extent and occurrence of vegetation associations be ground-truthed by field work.

A fundamental assumption underlying the preparation of the vegetation map was that there is a strong relationship between landform and drainage on the one hand and vegetation patterns on the other. This assumption is manifested in much of the vegetation mapping work conducted in Western Australia and more generally throughout the world, and in discussions of catenary sequences (for example, Beard 1980). It is important to note that the assumption is based on a generalisation which is often found to be inadequate for use in detailed studies of vegetation (Hopkins and Griffin 1984). In this study, we found exceptions to the generalisation, for example salmon gum woodland on lateritic uplands in the south west of the study area, which deserve further investigation.

Current Vegetation

Since European settlement over 23 580 ha (81.7%) of the original vegetation within the study area has been cleared. The remaining vegetation (5 290 ha; 18.3%) is highly fragmented, and is spread across 217 remnants. Table 4 shows that remnant vegetation occurs across a range of land tenures; 3 450 ha in nature conservation reserves, 130 ha on other Crown reserves, and the balance of 1 710 ha on private property. The remnants range in size from 0.26 ha to 1 261 ha, with a mean area of 24.4 ha.

Table 4: Land tenure of remnants in the study area

Remnant type	No. of remnants	Area of remnants(ha)	% of study area
Nat. Cons. Res	11	3 450	11.9
Other Reserves	4	130	0.5
Private	228	1 710	5.9

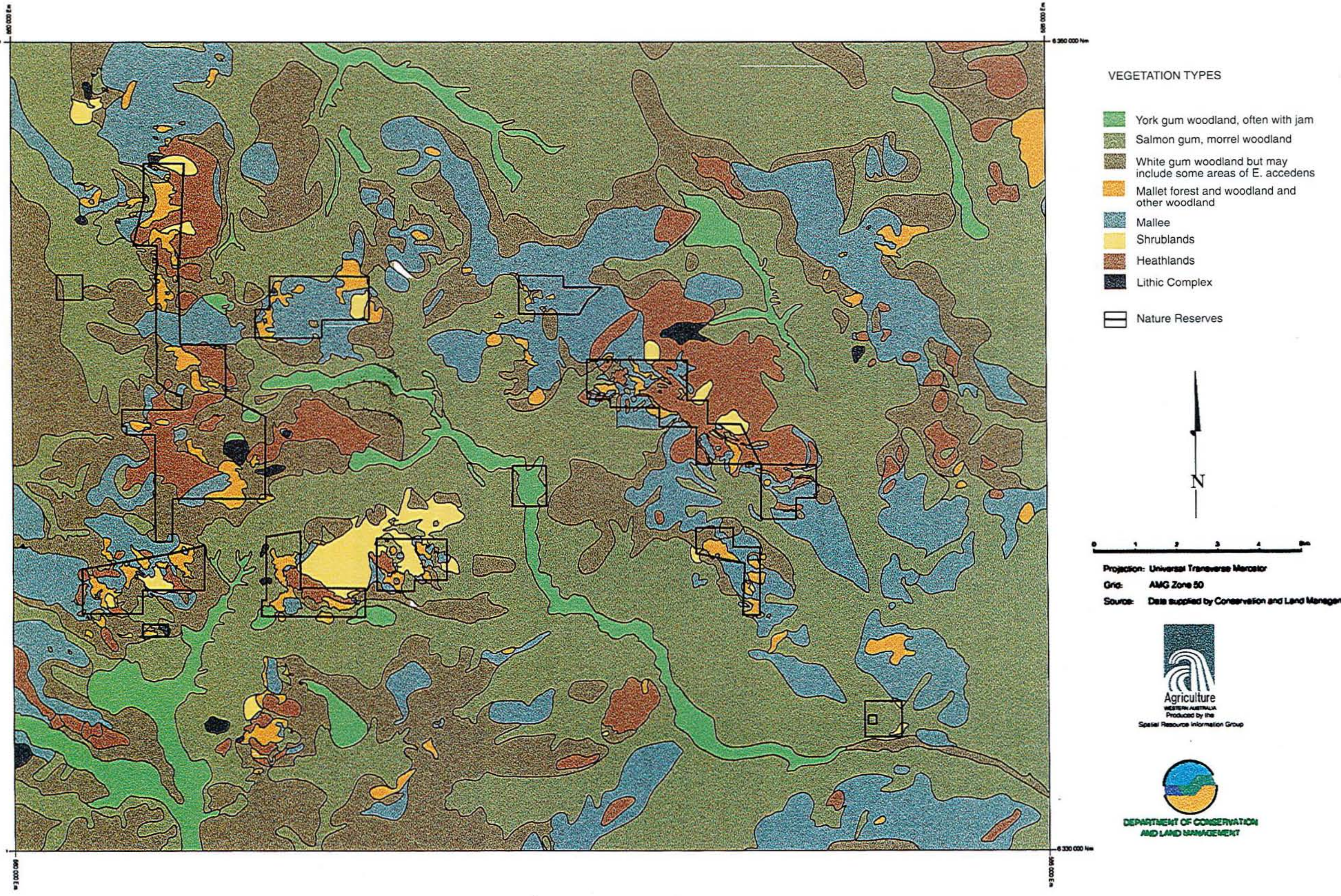
Table 5 shows the numbers of remnants within a range of size classes. The majority of remnants are extremely small; over two-thirds of all remnants are less than 5 ha in area. There are few large remnants, with only 7% of remnants over 50 ha in area. Aside from one private remnant of 156 ha in area, all remnants larger than 115 ha in size are nature conservation reserves.

Table 5: Size of remnants in the study area

Area of remnant	No. of remnants (ha)	% of total no. of remnants
< 1 ha	42	19.4
1-2 ha	51	23.5
2-5 ha	52	24.0
5-10 ha	35	16.1
10-20 ha	10	4.6
20-50 ha	12	5.5
50-100 ha	2	1.0
100-200 ha	4	1.9
200-500 ha	7	3.2
> 500 ha	2	1.0

Clearing has removed large areas of the original native vegetation, and fragmented the remainder. However, the impact of clearing has not been uniform across the landscape, with the more fertile, arable valley soils having been almost completely cleared. The less fertile and stonier upland areas have been cleared to a lesser extent.

Analysis of the map data shows that the present nature reserve system in the area is an unrepresentative sample of the landscape, being biased towards the upper parts of that landscape. Whilst there are some obvious historical factors



Map 4: The probable distribution of native vegetation in the study area prior to broadscale clearing for agriculture

that gave rise to the current reserve system (see "History of the Dongolocking Study Area"), the data reinforce the commonly stated view of reserves as "worthless land" (Pouliquen-Young 1995).

While 12% of the study area lies within the nature conservation reserve system, less than 6% of the original area of York gum and salmon gum woodlands, growing in the valley bottoms and along stream lines, are reserved. In sharp contrast, about 67% of the original area of mallet forests and woodlands, which grow on lateritic uplands and breakaways, are reserved.

The picture is similar when comparing the proportion of all remnants that are protected within the reserve system. Most vegetation types have at least 70% of their total remaining area within the reserve system, however only 28% and 32% of York gum and salmon gum woodland remnants are reserved respectively.

Table 6 highlights the massive changes that have affected vegetation types lower in the landscape, predominantly York gum and salmon gum woodland. Salmon gum woodland was originally the most widespread vegetation type within the study area, covering nearly 12 000 ha (41%). It was also the most extensively cleared (91%). Only 3% of its original extent is protected in nature conservation reserves, making it the most poorly represented vegetation type within the study area. The conservation of these woodland ecosystems is a major conservation task.

Many of the Dongolocking reserves were originally set aside to protect stands of mallet for the tannin industry, and occupy a relatively high position in the landscape. They were later reserved for the conservation of flora and fauna. Vegetation communities occurring lower in the landscape, such as woodlands of morrel, York gum and salmon gum, are not adequately reserved within the study area, and have been largely cleared for agriculture (Beard 1980). The poor representation of lowland vegetation types in the reserve system poses some conservation dilemmas for conservation planners and managers, through this project and into the future. While revegetation efforts must be focused on farmland adjacent to existing patches of native vegetation, some attention must also be paid to restoring natural, functioning ecosystems in the lower parts of the landscape.

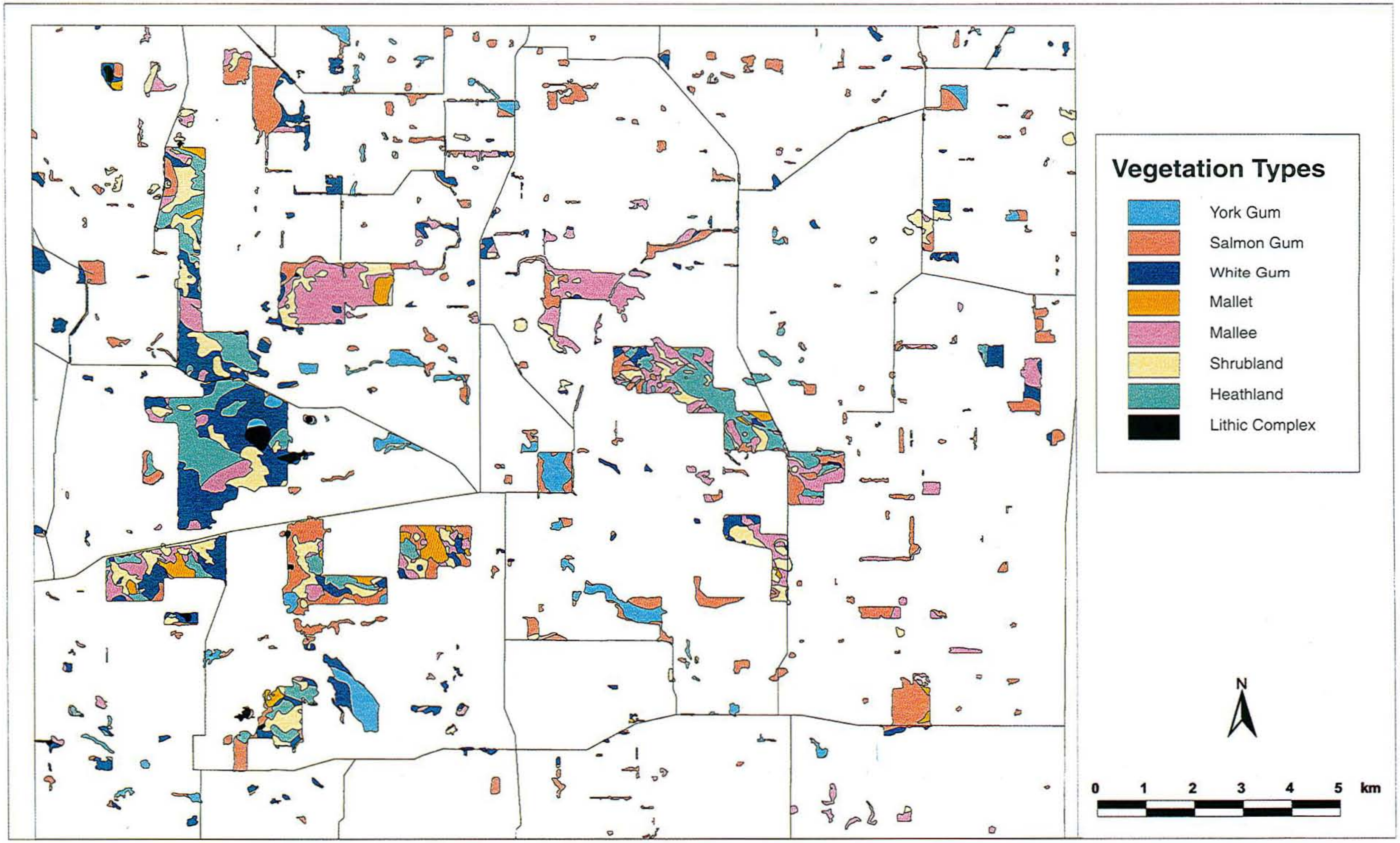
Most natural vegetation in the study area now remains in a set of local nature reserves, although there are important areas in other reserve types and on freehold land. Most of our detailed knowledge of the local vegetation comes from surveys of the nature reserves.

Analysis of the vegetation data from the above surveys reveals that 402 plant species have been recorded for the reserves within the study area, distributed amongst the following formations:

- woodland/forest 232 species
- mallee 183 species
- heath 183 species
- shrubland 97 species
- lithic complex 8 species

Table 6: Extent and reservation of vegetation types in the study area

	Original Vegetation	Current Vegetation in Remnants		Current Vegetation in Nature Conservatin Reserves		
Vegetation Type	**Area (ha)**	**Area (ha)**	**% of original**	**Area (ha)**	**% of original**	**% of current remnants**
York gum woodland	1 480	330	22	91	6	28
Salmon gum woodland	11 920	1 090	9	353	3	32
Wandoo woodland	6 320	940	15	677	11	72
Mallet forest/woodland	930	690	75	623	67	90
Mallee	5 000	1 150	23	816	16	71
Shrubland	590	160	28	154	26	96
Heathland	2 510	880	35	707	28	80
Lithic complex	120	50	45	35	30	70
TOTALS	**28 870 ha**	**5 290 ha**	**18 %**	**3 450 ha**	**12 %**	**65 %**



Map 5: The distribution of vegetation types throughout the study area

Table 7: Vegetation associations and total species recorded during surveys

Survey	Reserves	Number of Plant Species	Number of Vegetation Associations			
			Woodland	Mallee	Shrubland	Heath
Napier *et al.* 1986	19089 19090	205	10	13	2	12
Napier 1986	26005	15	3			
Mattiske 1996	19086	82	5			1
Backshall 1985	19085 19091 20069 20070	163	8	12		7
Muir 1978	19082 19083 19096	230	11	8	2	11

This is likely to be a considerable underestimate of the flora of the study area, as many annual species will have been missed, and the surveys were focused on vegetation description, rather than floristics.

Fauna

Mammals

Within the Wheatbelt Administrative Region as defined by CALM, a total of 53 species of native mammals have been recorded (Sanders and Harold 1991). Nine species have become extinct within the Wheatbelt Region since European settlement, and a further ten are considered at risk. Of the 34 native species recorded by Kitchener *et al.* (1980a) for the wider wheatbelt (includes wheat-growing areas outside CALM's Wheatbelt administrative boundaries), only 12 were considered to be moderately common. Most of the mammal species recorded for the wheatbelt have much wider distributions, and only the western mouse (*Pseudomys occidentalis*) is largely confined to the Region (Kitchener *et al.* 1980a). The wheatbelt is also the distributional limit for several of the native rodent species recorded (Kitchener *et al.* 1980a).

Within the study area thirteen native species, including four bats, have been recorded since the early 1970s. It is difficult to establish how many species have become locally extinct, but historical records from nearby Tutanning Nature Reserve suggest that the following species are also likely to have occurred at Dongolocking prior to European settlement, but have become locally extinct (A Hopkins personal communication):

Tammar	*Macropus eugenii*
Crescent Nail-tailed Wallaby	*Onychogale lunata*#
Mernine - (Banded Hare Wallaby)	*Lagostrophus fasciatus*
Woylie	*Bettongia penicillata*
Boodie	*Bettongia lesueur*
Nguara - (Common Ring-tailed Possum)	*Pseudocheirus peregrinus*
Bilby	*Macrotis lagotis*
Quenda	*Isoodon obesulus fusciventer**
Marl - (Western Barred Bandicoot)	*Perameles bougainville*
Chuditch	*Dasyurus geoffroyi*
Numbat	*Myrmecobius fasciatus*
Heath Mouse	*Pseudomys shortridgei*

\# *The Crescent Nail-tailed Wallaby is extinct, all other species survive elsewhere.*

* *Quenda were recently translocated into the Dongolocking Reserves and the population is now well established (see page 41 for details).*

Herpetofauna

A total of 118 species of reptiles and 18 frogs have been recorded for the Wheatbelt Region (Sanders and Harold 1991). The reptiles can be further divided into the following numbers of species:

- 1 freshwater tortoise;
- 88 lizards;
- 3 non-venomous snakes;
- 21 venomous snakes; and
- 5 blind snakes.

There is no record of any herpetofauna becoming extinct since European settlement (Sanders and Harold 1991).

Kitchener *et al.* (1980b) identified the lizard assemblage of South-western Australia as comprising representatives from five lizard faunas (West Coast, South-West Coast, South Coast, Inland, and Wide Ranging). The majority of lizards within the Wheatbelt Region are from the Inland and Wide Ranging Groups.

Within the study area a total of 9 frog and 25 reptile species have been recorded in surveys since the 1970s, including:

- 7 geckos;
- 8 skinks;
- 1 dragon;
- 4 legless lizards;
- 1 monitor;
- 1 venomous snake;
- 2 blind snakes; and
- 1 python.

The lizard fauna of the Dongolocking study area is dominated by species from the Inland and Wide Ranging Groups, but also contains several species from the West/South-West Coast lizard fauna (Kitchener *et al.* 1980b).

Birds

The broader wheatbelt lies in a transitional zone between the wetter southwestern forests and the arid zone, and accordingly the avifauna contains elements from both zones (Saunders and Ingram 1995). A total of 195 bird species (excluding vagrants) have been recorded for the wheatbelt (Saunders and Ingram 1995). Changes to the landscape with the advent of agriculture have had a major impact on wheatbelt birds. Nearly half of all species have declined, almost one fifth have increased, and the remainder have had no detectable change in either their range or abundance (Saunders and Ingram 1995).

Within the Dongolocking study area a total of 95 bird species have been recorded. Many species still present at Dongolocking have either become locally extinct or are declining in other parts of the wheatbelt. Work at Kellerberrin (summarised by Lambeck 1998) and other studies of birds in the agricultural region (Saunders and Ingram 1995) suggest that there are at least 30 bird species which occur in the Dongolocking area that are decreasing in numbers elsewhere in the agricultural region (Table 8, page 32). Surveys of selected remnants were undertaken to assess the status of these and other bird species in the Dongolocking area. Table 11 (page 33) shows the proportion of 70 surveyed remnants on which each bird species was observed during these surveys. Of the 30 species that are potentially vulnerable, 12 were recorded on less than 10% of the remnants surveyed and 17 were recorded on fewer than 20% of the remnants. Interestingly, some species, such as the rufous tree creeper, the yellow plumed honeyeater and the grey currawong, that are known to have disappeared from other parts of the wheatbelt, were quite common in the Dongolocking area.

Thirty-one additional species that were not expected to be at risk were also infrequently sighted. This does not mean that they are all vulnerable. There are a number of reasons why some of these species were not observed. Some, such as rainbow bee-eaters, cuckoos and white-fronted chats, are seasonal migrants and had not yet arrived in the study area at the time of the surveys. Others mostly live in paddocks and on farm dams and hence, while not recorded in the remnants, were likely to be present in the surrounding agricultural land. These include the little button quail, Richard's pipit, brown song lark, wood duck, mountain duck and black-fronted dotterel. Some species such as the pied butcherbird, black-faced wood-swallow and elegant parrot are expanding into the area from adjoining regions and hence their low numbers is no cause for concern.

It is possible that some bird species have become locally extinct. However, it is extremely difficult to identify these due to a lack of appropriate historical records. Based upon a lack of recent records it is reasonable to surmise that the emu has become locally extinct. The loss of the emu from local ecosystems may have important consequences for the regeneration of some plant species (A Hopkins personal communication).

Summary of Survey and Other Fauna Research

Fauna research is being undertaken within the study area on the movement of fauna between reserves and private remnants using recently established vegetation corridors. Results of this work have not yet been compiled.

The surveys used to develop the fauna lists are described on page 32.

Table 8: Species considered potentially vulnerable at Dongolocking based on regional patterns of avian decline (Saunders and Ingram 1995)

Inland Thornbill	Shy Hylacola	Restless Flycatcher
Western Thornbill	Striated Fieldwren	Long-billed Black-Cockatoo
Mistletoebird	Southern Scrub-robin	Western Rosella
Malleefowl	Crested Bellbird	Purple-crowned Lorikeet
Western Spinebill	Blue-breasted Fairy-wren	Red-capped parrot
Regent Parrot	Southern Emu-wren	Purple-gaped Honeyeater
Grey Currawong	Crested Shrike-tit	Yellow-plumed Honeyeater
Bush Stone Curlew	Western Yellow Robin	Tawny-crowned Honeyeater
Rufous Treecreeper	Hooded Robin	Brown Goshawk
Varied Sittella	Jacky Winter	Australian Owlet-nightjar

Table 9: Bird species previously recorded in the study area but not recorded in the current survey

Australian hobby	*Mulga parrot*	Southern emu-wren
Banded lapwing	*New Holland honeyeater*	*Spotted nightjar*
Cockatiel	*Pacific black duck*	Spotted pardalote
Crested pigeon	*Painted button-quail*	*Welcome swallow*
Crested shrike-tit	*Rainbow bee-eater*	Western spinebill
Little wattlebird	*Rufous songlark*	*Whistling kite*
Long-billed black-cockatoo	*Sacred kingfisher*	*White-plumed honeyeater*
Malleefowl	Scarlet robin	
Mistletoe bird	*Southern boobook*	

Species in italics were not considered at risk in spite of their low representation.

Table 10: Faunal groups and total species recorded during surveys

Survey	Reserves	Native Mammals	Reptiles	Frogs	Birds
Chapman *et al.* 1978	19082, 19083, 19096	10	23	7	82
Ninox 1987	19085, 19091, 20069, 20070	13	16	4	64
Total Species		**13**	**25**	**9**	**95**

Table 11: Proportion of remnants in the Dongolocking area on which each species was observed

Species	% occupied	Species	% occupied
Port Lincoln Ringneck	96	White-cheeked Honeyeater	15
Weebill	76	Silvereye	14
Red Wattlebird	75	**Regent Parrot**	13
Striated Pardalote	64	**Tawny-crowned Honeyeater**	13
Australian Raven	63	*Mountain Duck*	11
Australian Magpie	61	**Western Rosella**	11
Yellow-rumped Thornbill	57	*Elegant Parrot*	10
Grey Fantail	56	**Brown Goshawk**	8
Western Warbler	54	*Wedge-tailed Eagle*	8
Yellow-plumed Honeyeater	51	**Shy Hylacola**	8
Brown-headed Honeyeater	51	*White-faced Heron*	7
White-browed Babbler	50	*Fan-tailed Cuckoo*	7
Grey Butcherbird	47	**Western Thornbill**	7
Grey Shrike-Thrush	44	*White-fronted Chat*	7
Willy Wagtail	42	*Nankeen Kestrel*	6
Grey Currawong	40	**Southern Scrub Robin**	6
Galah	38	**Western Yellow Robin**	6
Australian Magpie Lark	38	*Black-faced Woodswallow*	6
Common Bronzewing	35	*Pied Butcherbird*	6
Purple-crowned Lorikeet	35	*Grey Teal*	4
Rufous Treecreeper	33	Peregrine Falcon	4
Brown Honeyeater	33	*Stubble Quail*	4
Yellow-throated Miner	32	*Tawny Frogmouth*	4
Tree Martin	31	**Blue-breasted fairy wren**	4
Black-faced Cuckoo Shrike	31	**Purple-gaped Honeyeater**	4
Inland Thornbill	31	*Little Eagle*	3
Varied Sittella	31	*Brown Falcon*	3
Singing Honeyeater	31	*Horsfield's Bronze Cuckoo*	3
Chestnut-rumped Thornbill	29	*Shining Bronze Cuckoo*	3
Red-capped Robin	26	*White-winged Triller*	3
Rufous Whistler	22	**Bush Stone Curlew**	1
Crested Pigeon	21	*Black-fronted Dotterel*	1
Dusky Woodswallow	19	**Red-capped Parrot**	1
Wood Duck	18	*Pallid Cuckoo*	1
White-eared Honeyeater	18	*Black-eared Cuckoo*	1
Laughing Kookaburra	17	**Owlet-nightjar**	1
Jacky Winter	17	*Richard's Pipit*	1
Restless Flycatcher	17	**Hooded Robin**	1
White-browed Scrub Wren	17	*Brown Song Lark*	1
Golden Whistler	15	**Striated field Wren**	1

Species in bold were those that were considered potentially vulnerable on the basis of work undertaken elsewhere.
Species in italics were not considered at risk in spite of their low representation - see explanation above.

by Terri Lloyd

Early History

The first settlement at Dongolocking was a pastoral lease taken up in 1885 (Klemm 1968, Chapman *et al.* 1978). This lease was based on Dongolocking Spring, which now lies within one of the Dongolocking Nature Reserves (Reserve No. 26005). At this time grazing was the only significant form of land use in the district. However, Doradine Spring (Williams Location No. 130) and the sandalwood well on Tembys' property (Williams Location No. 6217) were used as watering points by miners moving from Albany to the Kalgoorlie goldfields.

In the early 20th century, settlers came from two main sources - the Goldfields, which by then were in decline, and from South Australia which was troubled by drought (Moran 1969). Some sandalwood cutters who had worked through the area also returned and took up land for agriculture.

The Moran estate, "Tamarcurring", was taken up in 1901. This large holding totalled 8 000 ha and was mostly cleared during the period 1905-1930 (Moran 1969).

In 1906 three brothers of the Rankin family selected 5 000 acres of land without poison plants (*Gastrolobium* spp) to run some of the first sheep in the Wagin area. While jam trees (*Acacia acuminata*) were retained for stock feed, provided by foliage and seed that fell to the ground, York gum (*Eucalyptus loxophleba*) was ringbarked to encourage the growth of native grasses. A 2 000 yard dam supplied water (H Ball personal communication).

Other pioneering farmers included Hearnes, Pollards, Morrows and Ebsarys. Stewart and McPherson, also early settlers, took up land at "Horsebone Soak", a watering point for people travelling through the area by horse and cart.

The first wheat crop in the district was planted around the end of the 19th century (Klemm 1968). Between 1900 and 1913, although there was no mechanisation, there was rapid agricultural development. Development was temporally curtailed by a major drought in 1914 (Klemm 1968).

Most land at Dongolocking had been allocated to settlers prior to the outbreak of World War II. At this time the only restriction on clearing native vegetation was a prohibition on clearing mallet thickets. These thickets consisted mainly of brown mallet (*E. astringens*), but also blue mallet (*E. gardneri*) and silver mallet (*E. argyphea*). Mallet bark was used as a source of tannin for tanning animal hides. Stripping of mallet bark for tannin killed trees (Klemm 1968). Populations of mallet were so devastated early in the 20th century that regulations were introduced to protect the tannin resource.

Much land remained uncleared up until the 1940s due to the low profitability of farming and the difficulty of clearing land by axe. In the late 1920s the going rate for labour for land clearing was five shillings per day, and generally one man could clear one acre per day (Smith 1996).

Rich red loamy soils, considered best for agriculture because they were naturally richer in minerals, were selected and cleared first. These soils supported woodland vegetation. Common tree species on these soils are salmon gum (*E. salmonophloia*), red morrel (*E. longicornis*), York gum (*E. loxophleba*) and jam (*Acacia acuminata*).

Different methods of clearing were employed for second class agricultural land such as yellow sands over clay. These soils supported white gum (*E. wandoo*), rock sheoak (*Allocasuarina huegeliana*), mallee (*Eucalyptus* spp), and broom bush (*Melaleuca uncinata*).

After cutting taller timber with an axe, settlers used a team of horses pulling an eight foot long roller cut from bush timber to flatten vegetation. This was left to dry for later burning (Klemm 1968). A levered jack, known as a monkey grubber or monkey jack, was used in the 1920s to lever stumps from the ground. Mallees were chopped down at knee height and bark was knocked off the stump and then later burnt (Smith 1996).

Third class lands - such as shallow ironstones, deep sands and rocky areas of granite - were cleared last. This country supported poison plants (*Gastrolobium* spp), kerosene bush (*Dryandra* spp), banksias and Christmas tree (*Nuytsia floribunda*).

During the Great Depression (1929-31), landholders had to exploit all available resources, including the bush, to survive. Some farmers were forced by economic pressures to walk off their properties. Nearby farmland (about 4.5 km south of Reserve No. 19082) that belonged to the White family was abandoned and bush allowed to regrow. This block was re-cleared after World War II and now belongs to the Cook family.

Part of the early-cleared Rankin block also regrew including 33 ha of bush along the Dongolocking Creek protected by the Remnant Vegetation Protection Scheme since 1992. The large Behn Ord Estate was also allowed to "sucker" and grow up again. After World War II this land was divided into smaller blocks and released for Soldier Settlement (Smith 1996). The land was subsequently re-cleared for agriculture.

After World War II, manpower and other resources became available and grain and wool prices rose. With higher returns and fewer debts, farmers were able to continue the development of their land at a fast rate (Klemm 1968). War service blocks were offered to ex-servicemen. Areas considered to be viable units were offered. Farms of 2-2 200 acres were considered adequate if the land was of reasonable quality, and up to 2 500 acres if land was judged to be second-rate.

Soldier settlement on the family farms of Hughes' (near Reserve Nos 20070 and 20069) and Roberts' (close to Reserve Nos 19082 and 19084) did not require re-clearing like some other properties abandoned because of economic hardship. These farms were mostly cleared when part of the large estate of the Moran family, and were never allowed to revegetate.

Between 1945 and 1967 there was further large scale clearing in the Dumbleyung district due in part to the discovery that light land could be farmed by the application of trace elements. Also, clearing of land became easier. Immediately following World War II the then Public Works Department employed ex-servicemen who used army tanks and bulldozers left over from the war effort in Papua New Guinea (Smith 1996, R McLacklan personal communication). Rates for land clearing were considered reasonable and large areas of land were cleared quickly on the McLacklan, Smith and Hughes properties.

During the late 1940s and 1950s Mr. Britt Angwin had much success farming land considered second and third class alongside Reserve No. 19082. This success was due to the use of:

- high rates of superphosphate - considered excessive at two bags per acre,
- the sowing of nitrogen producing subterranean clover pasture; and
- application of trace elements.

Between 1924 and 1972 Dongolocking Reserve Nos 19096, 19082 and 10473 were set aside as timber reserves and managed by the then Forests Department for the protection and utilisation of mallet. Extensive "stripping" of mallet, which kills trees, took place between 1920 and 1930. However, the industry declined due to replacement of tannin with synthetic compounds and the development of cheaper sources of tannin. By about 1960 mallet bark stripping for tannin had finished in the south-west.

After World War II, as stripping of mallet for tannin extraction became uneconomic, the Forests Department lost interest in maintaining mallet stands. In many cases, if farmers were willing to strip bark and pay a royalty to the Forests Department, the Department would make blocks available for purchase (T B Angwin personal communication). This occurred when a Wagin farmer, Sir Crawford Nalder, held the position of State Minister for Agriculture. He was sympathetic to farmer requests for the further release of agricultural land (T B Angwin personal communication).

In 1954, 15 reserves referred to as the Dongolocking series by the Forests Department, had a total area of 4 048 ha. However, only 5% of this area carried mallet. Therefore five of these reserves were subsequently alienated and cleared for agriculture (Chapman *et al.* 1978).

On 23 June 1972 Dongolocking Nature Reserve was gazetted for the Conservation of Flora and Fauna and vested in the Western Australian Wildlife Authority (Chapman *et al.* 1978). The latter authority has been superseded by the National Parks and Nature Conservation Authority.

After 1975 land clearing was considerably quickened by the use of rake blades on bulldozers to clean up after burning fallen timber (T B Angwin personal communication). During clearing, shade patches were retained for livestock and bush was kept along creek lines prone to soil erosion. Many shade patches degraded by stock grazing have more recently been protected with fencing (T B Angwin personal communication).

The last block of land to be cleared at Dongolocking was on Willmotts' property in 1986 when 200 acres of a 300 acre block were cleared adjacent to Reserve No. 19091 on Location No. 14207. Other areas cleared in recent times include land on Location No. 15186 (240 ha) adjacent to Reserve Nos 19085 and 19086 by Moran's in 1972, and an area adjacent to Reserve No. 19096 by Thompsons in 1979.

In 1998, some 5 290 ha of native vegetation remains as remnants in the project study area. This includes 3 580 ha of Crown reserves and 1 710 ha of remnants on freehold land.

Despite the broad scale conversion of native vegetation for agricultural and pastoral practices, the remaining Crown reserves were left relatively undisturbed apart from timber cutting and mallet bark stripping. This was in part due to the widespread occurrence of native shrubs highly poisonous to domestic stock. Most common are box poison (*Gastrolobium parviflorum*), York road (*G. calycinum*) and prickly poison (*G. spinosum*). The presence of these and other poisonous plants ensured that stock were not grazed on the reserves. In many places seedlings of poisonous plants had to be grubbed on freehold land after initial clearing operations.

"A sheep poisoned by the toxic plants that abound on our lands must be treated thus - A slit ear to cause the blood to flow and strictly leave him alone. Movement means death, inaction and flowing blood could mean recovery" (Moran 1969).

Exploitation of Natural Resources

> "We ate what moved and cut down what didn't" (Smith 1996).

Between 1900 and World War I shopping trips were infrequent and cash was short. Landholders lived off the land to survive, especially during the Depression. A wide variety of wildlife was eaten including grey currawongs, bush stone-curlew, malleefowl, Australian ringneck parrot, Australian shelduck, bustards (especially at Christmas!), bronzewing pigeons (but, for fear of poisoning, not when poison bushes were in flower, and never the birds' bones), brush-tailed possums (*Trichosurus vulpecula*), western grey kangaroos (*Macropus fuliginosus*), western brush wallabies (*Macropus irma*), tammar (*Macropus eugenii*) , and, after their arrival in 1918, rabbits (Klemm 1968; Smith 1996).

"Opossum [brush-tailed possums] were in the thousands and nocturnal trips were made to Perth with the valuable skins of these protected varmints" (Moran 1969). The pursuit of kangaroos went on endlessly; the boys would silently fade into the bush and return with choice 'roo pieces and the precious skins to be scraped and pegged out for eventual sale.

Goanna salve made from the rendered fat of the long-tailed goanna (*Varanus gouldii*) was a cure-all for cuts and bruises. Of other natural medicines perhaps the most powerful was sandalwood oil.

"The most positive and potent repellent of flies and swiftest healer that I have ever seen is that clear yellowish pungent liquid extracted from sandalwood - the aromatic sandalwood oil. Its curative powers are almost magic and it repels infection" (Moran 1969).

While mutton was considered too valuable to eat as farmers were trying to build up flock numbers (Smith 1996), farm income was supplemented by the sale of possum, rabbit and kangaroo skins; the stripping and sale of mallet bark for tanning; sandalwood pulling; and manna gum collected from the manna wattle (*Acacia microbotrya*) for the confectionery industry. Manna gum was often collected by children. Most families had rugs made from either possum or rabbit skins. Kangaroo skin floor mats were also common.

Payments from mallet bark were between 1 and 5 pounds per ton in 1906 (Klemm 1968). After March 1907, when the railway line arrived in Dumbleyung, mallet bark was railed out by the railway truck load (Smith 1996).

Bush timber, mostly wandoo (also known as white gum), but also morrel uprights about 2.5 m long, and jam were used in the construction of houses and bough sheds. These were roofed with broom bush, grasstree (*Xanthorrhoea reflexa*), rock sheoak or tammar shrub (*Allocasuarina campestris*). After rain, seedlings would germinate in the roof dripline.

"The bough sheds where the family spent the long summer days - walls of brush wood that filtered the heat, the high pitched roof thatched with grasstree fronds - believe me those sheds really were cool" (Moran 1969).

Timber had many other uses. Feed troughs were constructed from hollowed out York gum and morrel trunks with a strip of hoop iron to brace both ends. A fine seven metre long trough is still in use in Claire Smith's garden. Large salmon gum and wandoo trunks were also used as rollers to knock down native vegetation on second and third class land in preparation for burning and ploughing. These rollers were cut green and then the centre was burnt out to form the correct thickness. Water was used to control the burning process. Rollers were about 1 m in diameter and 2.5 m long, and were pulled by a team of 4-5 horses. This land clearing technique was used up until the late 1950s.

Also, wandoo and jam trees were cut for fence posts, and early fences consisted of wooden posts with strands of wire rather than the later netting and ringlock. Sometimes jam posts were used in sheep yards, with race-ways constructed from posts positioned close together. Also, mallee roots piled high on top of each other were occasionally used for short sections of fencing and for the walls of small sheds.

Fire

A large fire swept through Dongolocking from the Narrogin area around 1927 (R Willmott personal communication). It is not clear how much of the Dongolocking study area was burnt during this fire.

All of Reserve No. 19082 has been burnt during the past 50 years (Chapman *et al.* 1978). Fires were frequent events when land was being cleared. Fires were used to clear the native vegetation, and often escaped. However, they were rarely large events. Most often they burnt to either the site of last years fire and subsequent reduced fuel levels, or to where farmland met woodland that generally had naturally low fuel levels. Rabbits and kangaroos would eat out up to four chain (about 80 metres) around crops, thus creating a "natural" fire break. Also, as a 6-7 bag per acre (1.3 tonnes/ha) crop was considered high yielding in those days, crop and stubble fuel levels were less than now and fires more easily controlled. Today, 12 bags per acre (2.4 tonnes/ha) crops are considered average, and they carry much more fierce fires.

Because of the larger amount of trees around, winds at ground level were less strong than today, and this also decreased the speed of a fire's run. In the 1940s, after harvest, farmers spent their time either slashing suckers (regrowth) or fighting fires (Smith 1996).

Recently, concern has been expressed that mechanical fire-breaks around reserves have not been maintained since 1993 and that fuel loads need to be reduced and veldt grass controlled to reduce a growing fire hazard.

Even with modern equipment, fire-fighting is demanding, tedious and sometimes very dangerous. The following description of fire by Moran (1969) captures the battle between early settlers and fire.

"Fire was a deadly thing in those days. A few men to defend a frontier of timber and dense scrub. If you were caught in scrub you'd had it. The fire moved fast and you couldn't. Anyway, there was no place to go.

Communication was poor. No 'phone, no walkie-talkie. Just horses for the spreading of alarm and a man away from the scanty fighters was a serious loss. Wet bags to beat with if there was any water to wet them, green boughs if available and a rake to clear a trail to light off. But fire travelled ahead of you through the tree tops and those cursed "willies" swirled by carrying debris and destruction where they willed. It's an awesome thing to listen to a big "willie" with a sound not unlike a jet, but still unseen and unpredictable. A big one could pick up a man and whisk him to destruction. These spinning devils could - and did - carry burning debris, even logs, up into the sky and drop them a mile away.

We were almost surrounded by reserves and endeavoured to thin them out in the off-season when the fire could be contained.

No wireless, no 'phone, no big trucks laden with water sprays, no district organisation to combat the fire devil. Just Smokey and me with sprays and an old Dodge for transport.

Joe's fire had ripped through far Hurdle Gully and was flinging burning leaves and debris across the Narrogin road and threatening "Tamacurring". It was mid-day and a scorcher. A good dam of water was close-by and we squirted knapsacks of liquid endlessly on the holocaust and replenished them by walking up to our necks in the dam. Returning dripping to the fire we would empty our sprays and once again soak our sizzling bodies.

We held it all the day long, and earlier perhaps than usual, the blessed Albany Doctor howled up to fling back the flames and the day was won. We'd had it but so had the fire. So that was O.K. and God bless the Albany Doctor. Then it was a matter of raking a safety line and burning back - making sure that the tall trees did not ignite - and of patrolling in the early dawn, building up a zone of safety before the heat and wind came again.

It is a fact that the heat of a great fire seems to attract moisture, so that often rain would help in the final reduction of a fire. Anyone who has endured years of fire menace comes to actively hate bush fire.

But, of course, the progress of the whole countryside depended on fire. It was friend and foe, servant and searing master."

Windstorms

Windstorms, or cock-eyed-bobs (tornadoes), occurred periodically including one that damaged many large salmon gums in the vicinity of the Tincurrin and 114 Gate Roads. In 1943 strong winds blew seagulls inland and Rob Smiths' pet pigeons away (Smith 1996). By far the largest windstorm occurred on April 15 1978 when Cyclone Alby blew top-soil onto fences and into patches of bush and moved weed seed into the area. Strong winds are predominantly from the north to northwest. These winds continue to blow agricultural weed seeds into bush including the reserve system.

Floods, Droughts and Seasonal Changes

The average annual rainfall at Dumbleyung, the closest recording station to Dongolocking, is 395.4 mm (median is 389.6 mm). In 1914 a severe drought on a national scale ruined wheat crops and many farmers found themselves in a desperate condition (Klemm 1968). Other dry years (annual rainfall less than 290 mm) include 1912, 1940, 1944, 1954, 1956, 1957, 1969, 1972, 1979 and 1994. During 1994, which included a particularly dry summer/autumn period, sheoak and wandoo died on ironstone ridges.

In living memory, 1955 is the best remembered flood year. Rainfall in this year (595.8 mm) was significantly boosted by a major summer cyclone, and the consequent flood caused significant structural damage to roads and railways. Other years that annual rainfall exceeded 530 mm were 1913, 1917, 1932, 1939, 1945, 1971 and 1983. These very wet years reflect either significant winter rainfall events, or major summer cyclones, or, as in 1983, a combination of both. Only three times this century has the Dumbleyung Lake overflowed into the Blackwood River.

That seasons cycle and change is shown by the comments of Moran (1969):
"In those days the climate seemed more vigorous; the sun blazed more fiercely, the cold was more intense. Maybe because of the vast areas of timber, dotted with small pockets of clearing. The heat in summertime was intense - timbers blanketed the wind. In the winter the water in the taps froze at night, clothes left on the line became rigid sheets and small pools froze solid. Grey, still, cloudy skies would persist for a week. Snow fell on occasions, sometimes enough to make snowballs and once a snowman. In our early youth we had snow-fights at "Tamacurring"."

Locust Plague

Between spring of 1990 and February of 1991 locusts hammered revegetation efforts and killed, in particular, sheoak species such as *Allocasuarina humilis*, rock sheoak and *A. microstachya*. Most bush areas recovered.

Rabbit Plague

Rabbits arrived in 1918, eleven years after the erection of the rabbit-proof fence just to the east of the Dongolocking study area. They were especially bad along sandy creek lines during World War II when there was a shortage of manpower to control rabbit populations. One of the methods used to control rabbits were wire traps around soaks. A trip around three such soaks could yield a spring cart filled with rabbits (Smith 1996).

The arrival of the rabbit virus, myxomatosis, in the 1940s was a God-send. Before the advent of the virus, many bush shade patches left on granite, deep sands and laterite were cleared to allow rabbit warrens to be ripped, and to remove rabbit cover.

Since 1953 oats poisoned with 1080 (sodium fluoroacetate) has been used to control rabbits. This poison occurs naturally in *Gastrolobium* spp shrubs, and native animals are far more tolerant to the poison than introduced species. Thus it is a much more selective poison than others used previously, such as arsenic, phosphorous and strychnine. The rabbit calicivirus, released in October 1996, has been disappointingly ineffectual in rabbit control.

Foxes

Foxes arrived shortly after rabbits and were a major problem in the 1950s because the release of myxomatosis virus and consequent decline in rabbit numbers caused foxes to shift their diet from rabbits to small native mammals. This caused a decline in many species of fauna including tammars, brush wallabies, brush-tailed possums, southern brown bandicoots and ground-nesting birds such as malleefowl, bush thick-knee and banded lapwing.

1080 in meat baits is now used as a control measure. Currently CALM has a major fox control program in many of the Dongolocking Nature Reserves. They have carried out monthly baiting since the middle of 1994.

Salt

At Dongolocking, the first sign of salt was around 1940 in Tembys' sandalwood soak on Williams Location No. 6217. The three metre deep soak had a water level of two metres and by 1942 was too salty for sheep to drink. Tembys' new Holden ute, used to cart water from the soak, then began to show signs of rust (Smith 1996).

Most of the Dongolocking study area is high in the landscape and salinity is not (yet) as dramatic as on the flats in surrounding areas. Salt was evident in the Doradine Creek south of the 114 Gate Road in the late 1970s, and has shown up on a section of the Dongolocking Creek south of the 114 Gate Road and west of Wishbone Road.

Water Resources

Moran (1969) recalls that: "Surface water was negligible and catchments were sunk at regular intervals. Boring produced nearly always salt affected water and was abandoned."

A small soak holds water during winter in the reserve referred to by locals as the Dongolocking Recreation Reserve (Reserve No. 26005, now a nature reserve), but there is no permanent, natural free water on the nature reserves (Chapman *et al.*. 1978). Water was carted from The Paperbark Soak, Reserve No. 9680, for district use. It was made into a Government dam with a quarter-stroke hand pump considerably speeding the water carting process (Bartram 1997). Water quality of a creek feeding out of the Spring was tested in July 1997 during a Blackwood River Snap-shot (a community water-testing project under the "Ribbons of Blue" program). The results were negligible levels of salt (30.4 ms/M), phosphorous (0.271mg/l), and nitrogen (2.09 mg/l).

According to farm rainfall records, in the past there was more rain and wetter winters than today (T B Angwin personal communication).

Aboriginal History

The Aboriginal history of the Dongolocking area has not been researched. Land in the area once belonged to the Wilmen tribe of the southwest, and the language spoken was one of the Nyoongar dialects. The name Dongolocking is thought to be a Nyoongar word meaning red wattle bird, a species that is abundant in the area.

In the 1930s Cyril Riley held a Conditional Purchase Block (Williams Location No. 1212) and this was sharefarmed by local farmers. Cyril's brother, Ron, cut fence posts from bush, picked dead wool and helped clear land for an income. Few Aboriginal families were resident at Dongolocking and Aboriginal people were usually on the move, particularly after the 1960s when they had their own cars and would turn up on farms looking for work (T B Angwin personal communication).

Cultural Values of the Dongolocking Bush

In a dry country with no permanent rivers and few semi-permanent water bodies, dams provided an important diversion. Moran (1969) remembers that:

"The big dam at Tam was a haven in early summer some 30 acres of water backed up and many water hens scurried in the scrub at water's edge. Black duck, Teal and Mountain Duck were in profusion and stately Black Swan sailed on the calm waters.

Even shag appeared on occasions. Tin canoes were constructed and rafts based on numerous four gallon petrol tins were poled happily over the lake.

A rigid control was enforced against destruction of bird life and the area became a wildlife sanctuary".

The Dongolocking Recreation Reserve (now a nature reserve, Reserve No. 26005) was the site for picnic sports. The first picnic was held on New Year's Day in 1910 when 30 people attended. After the third year about 250 people attended. The date was then changed to a day in October for convenience (Bartram 1997). Horse races, games and flat races during the day for the men, women and children were followed at night by dancing on the grass by the light of several fires (Klemm 1968). The game "Tilt the Ring" was popular amongst skilled horse riders, some of whom had been members of the 10th Light Horse Regiment. The game was later played on push bikes (H Ball personal communication).

The tradition of the Dongolocking picnic followed by a dance in the Dongolocking Hall continued until 1942 (Smith 1996). The Dongolocking community still gather together at the hall for the annual Christmas tree and social night.

Community Nature Conservation Projects

Dongolocking Corridors Project

The Dongolocking Corridors Project began in 1991 with a plan to fence 30 km of unformed, one chain wide, road reserve. Many of these road reserves provided good connections between bush reserves. In 1992 corridors fenced in 1991 that had been cleared were revegetated using seed collected from local native plants. A community initiated study to determine what birds, frogs, small mammals and reptiles use three revegetated corridors of varying widths and lengths began in 1992/93 with initial high levels of support from CSIRO and CALM. The study is carried out by local volunteers and involves quarterly pit trapping and bi-monthly bird surveys. This project will finish in 1999.

The project group have also been active in acquiring funds to fence over 300 ha of bush, and to map flora and survey the vegetation of corridor study sites. Road reserves have been widened and gravel pits revegetated in co-operation with the Dumbleyung Shire Council - for example, those on Dwelyerdine and Tincurrin Roads.

Dongolocking Reserves Bird Banding Project

Marion Massam began work in March 1995 under the Australian Bird Banding Association on a six-year long project to colour band seven key bird species resident at Dongolocking that have either become extinct or are rare nomads in the northern wheatbelt. With 1 200 captures to date Marion will document the movement of birds through revegetated corridors as compared to bush blocks without links to the reserve system, plus general occurrence and abundance of bird species at Dongolocking.

Most Dongolocking farming families have helped with either the corridors or bird banding projects over the past five years.

Changes in Native Species Abundance

Mammals

Small mammal populations started to decline after the 1920s (T B Angwin personal communication). Bilby (or dalgyte, *Macrotis lagotis*) burrows are remembered by older residents. It is thought that rabbits out-competed bilbies for food and were easy prey for the fox.

The only locally extinct animal that has been re-introduced is the quenda (*Isoodon obesulus fusciventer*). This was re-introduced to a local nature reserve by CALM in October 1994. Originally introduced into Nature Reserve No. 19082, they have since been sighted in Reserve No. 19090. They are commonly seen now by Richard Moran when he is harvesting at night near Nature Reserve Nos 20070 and 20069. The Angwin family reported 80 sightings of bandicoots during the 1997 grain harvest.

In the early 1950s, Roy Willmott saw a chuditch (*Dasyurus geoffroyi*) crossing Wishbone Road in the Dongolocking area (R Willmott, personal communication).

Of other mammals, the most recent record of a numbat (*Myrmecobius fasciatus*) was on "Lensfield" in 1935 (Smith 1996).

Two farms in the Dongolocking area were named after the tammar - "Tamarcurrie" the Angwin family farm and "Tamarcurring", the Moran family farm. While there have been possible sightings of tammars, most recently by Dick Betterley in 1992 on Reserve No. 19082 whilst on a Central Great Southern Naturalists excursion, their continued presence has not been irrefutably shown.

Brush wallabies used to be in their hundreds. While now very uncommon, their numbers seem to be increasing with fox baiting (T B Angwin personal communication). A group of six are commonly seen feeding at dusk in farmland adjacent to Reserve No. 19082.

Young, male red-tailed phascogales (*Phascogale calura*) are frequently taken by household cats especially during dispersal in late spring and summer. Of the native mammals remaining at Dongolocking, red-tailed phascogales are the most threatened species (State, national and international listings).

The Smith family saw a dingo on Reserve No. 19091 while on a Sunday drive in 1967. There are no more recent records, although these animals were a problem for early settlers. Moran (1969) recalls that: "Dingoes were a major hazard of the thinly settled times when "Tamacurring" was on the edge of proper settlement. Aniseed was a lure of great power in leading dogs to a bait which was treated with strychnine - a certain killer."

It appears that dunnarts (*Sminthopsis* spp) are decreasing in numbers on farmland (R Willmott personal communication).

Another animal that has declined is the brush-tailed possum. While once in their thousands in the early part of this century, Smith (1996) recalls that: "I don't think that I would see two possums a year now travelling around."

Birds

Until the record of a malleefowl in Reserve No. 19082 by CALM employees Ken Wheeler and Mal Graham in October 1995 (K Wheeler personal communication), they were last recorded by Richard Moran in the early 1980s crossing Dongolocking Road to Reserve No. 19085 to a sheoak thicket.

It was once common to see flocks of 1-200 regent parrots, but now they have almost disappeared (T B Angwin personal communication). However, the bird seems to be making a small come-back and is now seen in flocks of up to fifteen.

Of general interest is Smith's (1996) comment that: "There was more in the insect/meat-eating type of bird than today - crows and magpies more predominant, now it's mainly grain eating birds."

Emu - one only seen by long term resident (T B Angwin personal communication).

Western rosellas were reported by the Museum survey (Chapman *et al.* 1978) as moderately common, but they are now uncommon in and around the Dongolocking Reserves.

White-tailed black cockatoos seemed to leave after the galahs came down from the north (H Ball personal communication), although they are still seen on the Tincurrin sandplain and at Dudinin town reserve. During the Museum survey in 1974 (Chapman *et al.* 1978), three birds were seen feeding in a paddock in the Dongolocking area and later on wandoo. Birds were also sighted by Richard Moran two seasons ago in Reserve No. 19085 in banksia and jam country west of Moran Road.

Purple-crowned lorikeets were extremely common and it was possible to collect quite a few dead outside the Dongolocking school where they had tried to fly inside but had killed themselves on the windows (Smith 1996). Flock numbers have declined from groups of several hundred to groups of 30 birds or so.

Silvereyes were reported as uncommon during the Museum survey, and small numbers still occur.

Banded lapwings, after declining, seem to be increasing with flocks of 30 on farmland not uncommon. This species declined with the introduction of the fox, and later, the use of DDT on farmland in the 1950s.

Bush stone-curlew - another ground-dwelling bird that has declined in numbers is the bush stone-curlew. It remains in small numbers in the reserve system and on nearby farmland.

Australian bustard - an uncommon vagrant in the Dongolocking area.

Collared sparrowhawk and peregrine falcon - both were shot when attacking cage birds including poultry.

Australian wood duck arrived after World War II around 1945 (H Ball personal communication). These ducks continue to increase in number.

Galahs are another recent arrival, and reached Dongolocking within the last 40 or so years. During the Museum survey a pair were recorded over shrubland in the reserves, and 13 were recorded at Dumbleyung Townsite 20 km from Dongolocking. They are now in large flocks and, like the Australian Ringneck, are considered a pest species because of the damage they cause to seedlings, older established trees and grass trees.

Pied butcherbirds appeared in the late 1980s (Smith 1996).

Yellow-throated miners were not recorded in the Museum survey, but have always been present at Dongolocking in low numbers in good patches of bush. They are common in degraded woodland (Saunders and Ingram 1995).

Crested pigeons came at the same time as the galah in the 1950s (H Ball personal communication). It was formerly a species of savanna woodlands lining the watercourses of the arid zone. In developing the wheatbelt, extensive areas resembling riverine plain have been created, with scattered woodland, introduced grasses, and water points in nearly every paddock. This provides habitat ideal for this species (Saunders and Ingram 1995).

Reptiles and Frogs

As elsewhere in the country, carpet pythons (*Morelia spilota imbricata*), which are much less common now, were encouraged and protected in hay and grain sheds and used to control rats and mice. Less fortunate were dugites (*Pseudonaja affinis*) and other poisonous snakes. These were run over by vehicles, shot and attacked with rakes and spades. An attitude of "kill every one you see" still exists.

Frogs have definitely declined (Smith 1996).

Native Plants

Smith (1996) notes that: "The good orchid country - jam, sheoak and white gum [wandoo] country is mostly all cleared now, apart from a few reserves. I'd have to really think hard now to be able to take you to a patch of good orchids."

Everlastings, outcompeted by weeds, grazed by sheep and susceptible to herbicides, are now extremely uncommon on farms, but they sometimes persist on and around granite outcrops.

Sandalwood was once common, but very few trees remain. A small stand remains on the western end of the 114 Gate Road Reserve.

Introduction of Weed Species

Existing plantations of tagasaste (*Chamaecytisus palmensis*), olives (*Olea europaea*) and pine (*Pinus* spp) have some potential to become weeds in the future.

Bridal creeper (*Asparagus asparagoides*) was grown in gardens of the 1930s when it was in demand for funeral wreaths and wedding bouquets (B Smith personal communication). The plant was also commonly used in gardens in the 1950s and later.

Rye grass (*Lolium* spp) was sown in the 1950s for sheep feed.

Barley grass (*Hordeum* spp) and wild oats (*Avena* spp) were introduced with the first wheat crops at the time of land settlement and in manure of sheep.

Veldt grass (*Ehrharta calycina*) was introduced in the 1950s to stabilise light soils and provide sheep feed. It was easily grazed out and only established well where it wasn't prone to grazing, for example, road reserves and bush blocks. It now outcompetes native vegetation and has become a major weed problem and fire hazard on Reserve Nos 19082 and 20070.

Wild radish (*Raphanus raphanistrum*)and wild turnip (*Brassica tournefortii*) became a problem with increased cereal cropping in the 1960s.

Management of Crown Reserves

Crown reserves in the Dongolocking study area are the most important areas for nature conservation. If bush had not been set aside in timber reserves, water reserves and other reserve types, most of the native plants and animals would have disappeared.

However, these reserves have not always been well thought of. Moran (1969) noted that "mallet reserves were commonly seen as a harbour for all vermin that crawled, slithered and hopped."

Most of the areas that are now nature reserves were originally set aside as timber reserves and managed by the Forests Department. During the 1970s, most of these reserves were converted to nature reserves managed by the Department of Fisheries and Wildlife. With the formation of the Department of Conservation and Land Management in 1985, management was transferred to that Department.

The story of establishing these reserves, the battles to retain them, and the history of their management is an important one. Unfortunately, there has been no time to document this story during the current project.

DEMOGRAPHICS AND NEEDS OF FREEHOLD LAND MANAGERS

by Bruce H. Bone

Introduction

In "Land Management at the Landscape Scale - a Framework" the importance of human needs as an environmental component are stressed. This section documents the expressed needs of freehold landholders within the project area. This group are the major landholders within the project area, and the success of this plan is dependent on their willing and positive involvement in implementation of management works.

The second largest land "owner" in the study area is the National Parks and Nature Conservation Authority (NPNCA) in whom all nature reserves are vested. The Department of Conservation and Land Management (CALM) manages nature reserves for the NPNCA and has relevant statutory powers. The objectives and management policies of CALM are written in various documents, therefore the "needs" of CALM as landholders are not described in this paper. Other landholders in the study area control much smaller areas of land, and their needs are not described in this document.

The needs of freehold landholders were described through a series of interviews conducted by an officer from CALM. The aims of these interviews were to document:

- the social structure of the project area;
- landowner opinions of agricultural values and threats;
- landowner opinions of remnant vegetation values and threats;
- landowner opinions of nature reserve values, threats and management issues; and
- landowner attitudes to revegetation, previous works and future intentions.

Survey Methods

A questionnaire was developed based on the above goal and advice from various social researchers working in agriculture and conservation. The questionnaire was also circulated to the Project Steering Committee for their comment.

Due to time and resource constraints, this survey targeted landholders adjoining nature reserves within the study area. However, this involves most landholders in the study area (17 of the 21 landholders in the study area), so the survey is representative of the study area as a whole. In the survey a "landholder" is a single management unit, and may represent more than one family.

Seventeen questionnaires were completed. Surveys were conducted between 16 and 27 June 1997, and began immediately after seeding had finished. Respondents could give more than one answer to multiple-choice questions, however, only one response is possible for some questions.

Information from landowners was generally obtained by personal interview based on the questionnaire. In three cases where this was not possible land managers completed and returned questionnaires. The survey was separated in to six major sections (total of 45 questions). Each section addressed a particular area of information as follows:

Social Structure: Information on property ownership, age structure, decision making, town association, local interactions and connections with a catchment group.

Agricultural Values and Threats: Information and landowner opinion related to physical property descriptions, farming activities, farming methods, and threats to farming (physical and economic).

Remnant Vegetation Values and Threats: Landowner opinions of remnant vegetation including descriptions, values, threats and management barriers.

Nature Reserve Values, Threats and Management Issues: Landowner opinions on the value, use, threats, management problems and impacts of nature reserves.

Revegetation: History of revegetation activity (type and reasons) and future intentions.

Information/Plan Requirements: Assessment of landowner information requirements and format of information to be supplied.

The results of the survey are discussed under each of these section headings below.

Social Structure

Family Units

Of the 17 properties surveyed, nine are owned and operated by a single family unit, five by two family units, and three are owned and operated by three family units. A family unit was defined as an independent adult/s with associated family members.

1 Family Unit:	53%
2 Family Units:	29%
3 Family Units:	18%

Age Structure

The total population living on the 17 properties is 78 with a range of ages. The largest age group is the 30–50 years category (35%), and the smallest is the 20–30 years group (8%).

Table 12: Age structure

Age Group	Number of people	% of total population
0-10 years	12	15%
11-20 years	16	21%
21-30 years	6	8%
31-50 years	27	35%
51+ years	17	22%
Totals	**78**	**100%**

Length of Property Ownership

When landowners were asked how long they had owned their properties, all gave answers in terms of their overall family ownership and not their personal ownership. The average length of ownership is 45 years with a range of 6–85 years.

Town Association

Landowner responses concerning the town they associate with (social, business) varied with property location. In general terms the northern section of the project area has a stronger connection with Narrogin and the southern section a stronger connection with Dumbleyung. There is also some association with Wagin on the western side of the project area.

Table 13: Town association

Town(s)	Number of responses	% of total responses
Narrogin	6	35%
Narrogin and Dumbleyung	4	24%
Dumbleyung	2	12%
Wagin and Dumbleyung	2	12%
All three towns	3	18%
Totals	**17**	**100%**

Interactions with Other Landowners

When asked about interactions with other landowners in the project area (map shown to each respondent) 24% (4) said they have wide interaction with landowners across the area. Other responses suggest three broad interaction/social groupings:

1. east along fence road;
2. south from the Dongolocking road; and
3. north from the Dongolocking road.

These groupings (north and south) are mainly influenced by school bus coverage, either Dumbleyung or Tincurrin, and to the east by a catchment boundary.

Table 14: Interactions with other landowners

Mostly with Wickepin Shire people	2 (12%)
Mostly with Dumbleyung Shire people	6 (35%)
Neighbours	3 (18%)
Interacts with all people	4 (24%)

Agricultural Values and Threats

Physical Descriptions of Properties

The total area included in the survey was approximately 32 113 hectares as estimated by respondents. As the criterion for selecting landowners for the survey is that they adjoin a nature reserve, some areas outside the project area may have been included in responses. The median property size is 1 800 hectares with a range from 812 – 3 840 hectares.

Landowners estimated that 91% (median) of properties were used for agricultural production with a range from 80–98 %. The median age of properties (based on time since first clearance) was 85 years (range 45–100 years) and most clearing stopped 32 years ago (median, range 15–40 years). Note that the last clearing in the study area was undertaken in 1986 (see "History of the Dongolocking Area").

Farming Enterprises

Responses give cropping as the major farming activity as judged by area used. On average, cropping accounts for 58% of farming enterprises, and comprises a broad range of products including cereals, pulses and oils. Sheep grazing, with 42%, is the second largest activity. The mix of enterprise activities ranged from 30% cropping with 70% grazing, to 60% cropping with 40% grazing. Pastoral activity includes both wool and meat production. A majority (59%) of landowners indicated they had increased their cropping activities and reduced grazing in recent years while 41% indicated their enterprise ratios had not changed.

Property owners gave low commodity prices and rising input costs as the main economic threats to their enterprise. Other significant threats mentioned included restrictions on chemical use, government policy, and international policies.

Table 15: Economic threats to farm profitability

Threat	Number of responses	% of landowners
Political manipulation	2	12%
Low commodity prices	5	29%
Increased cost of inputs	5	29%
Green movement	1	6%
Restrictions on chemical use	2	12%
GATT policies (international)	2	12%

Farming Systems

Most respondents (59%) are using a combination of conventional and minimum tillage practices, with 29% using all minimum tillage or direct drill farming methods. A small percentage of farmers (12%) were still using conventional, multiple-pass operations.

For those landowners using the combination of methods, the average time since beginning to use minimum tillage practices was nine years. The initial incentive for change was wind erosion. Those using all minimum tillage or direct drilling had been using the practice for an average of five years.

Some of those continuing with conventional tillage methods had not taken up new practices because they are concerned with the dependence on chemicals required with reduced cultivation.

The most widely identified physical threat to the farming enterprise was wind erosion followed by soil compaction and salinity. Chemical resistance among weed plants was also viewed with concern.

Table 16: Physical threats to farm profitability

Threat	Number of responses	% of landowners
Wind erosion	5	29%
Salinity	4	24%
Compaction/soil structure	4	24%
Herbicide resistance in weeds	3	18%
Water erosion	1	6%
Weather changes	1	6%

Remnant Vegetation Values, Threats and Management

Physical Characteristics

Based on farmer responses, 9% of farm area (median value) is covered in remnant native vegetation with a range of 2–20%. When asked how this was distributed, 35% (6) stated that it was in blocks, 29% (5) said it was in a mixture of blocks and strips, 24% (4) indicated it was distributed as a mixture of blocks, strips and individual trees, and 12% (2) said it was in strips only. A majority of landowners considered that the vegetation was of a woodland structure (65% (11)) while 35% (6) indicated a mixed structure of both woodland and shrubland.

Values

Most responses linked the value of remnant native vegetation to land degradation issues. Specific values mentioned were: windbreaks by 35% (6), water usage for re-charge control by 29% (5), and land protection by 6% (1). Environmental and landscape values provided by remnants were also highly regarded by respondents. In this case perceived values included fauna habitat by 24% (4), aesthetics by 29% (5) and wildflowers by 12% (2). Values for the farming enterprise, such as stock shelter (29% (5)) and a source of fence posts (6% (1)), were also responses.

Table 17: Landowner values of remnant vegetation

Value	Number of responses	% of landowners
Wind breaks	6	35%
Stock shelter	5	29%
Water usage	5	29%
Aesthetic	5	29%
Fauna habitat	4	24%
Wildflowers	2	12%
Land protection	1	6%
Fence Posts	1	6%

Management Activities

The need to fence remnant native vegetation was widely recognised by landowners across the project area with 82% (14) having fenced some of their remnants to exclude stock. One farmer said that efforts were also being made to control weed and vermin populations in the remnant vegetation on his property.

Table 18: Landowner management activities

Activity	Number of responses	% of landowners
Fencing	14	82%
Weed control	4	24%
Vermin control	1	6%
Nil	3	18%

Barriers to Management

Although most landowners recognised the need for better management of remnants, they regarded both time (35% (6)) and cost (47% (8)) as significant barriers to improving management. The requirement to utilise remnant vegetation for stock shelter by 12% (2) also became a conflicting use and a barrier to changing management practices for some landowners. A lack of information was regarded by 6% (1) as a barrier.

Table 19: Barriers to landowner management activities

Barrier	Number of responses	% of landowners
Cost	8	47%
Time	6	35%
Need for stock shelter	2	12%
Lack of information	1	6%

Threats To Remnant Vegetation

Forty one per cent (7) of landowners regarded stock grazing as the single largest threat to remnant vegetation on their properties. The combined impact of other herbivores, both native and introduced, was also regarded as highly significant by 47% (8) of landholders. Other factors regarded as threats included senescence by 12% (2) and a lack of regeneration by 12% (2). Respondents who were located in the flatter portions of the landscape stated (18% (3)) that salinity could potentially be a threat even though it wasn't presently a problem. 18% (3) of respondents said weed invasion was an ongoing threat and one landholder saw impacts from surrounding land use also as a threat (for example, spray drift, weed and nutrient importation).

Table 20: Threats to remnant vegetation

Threat	Number of responses	% of landowners
Stock grazing	7	41%
Rabbits	4	24%
Weed Invasion	3	18%
Salinity	3	18%
Senescence	2	12%
Lack of regeneration	2	12%
Kangaroos	2	12%
Wildfire	2	12%
Nutritional deficiency	1	6%
Predators (foxes & cats)	1	6%
Surrounding land use eg spray drift, weed & nutrient importation.	1	6%

Interactions of Remnant Vegetation and Agricultural Enterprises

Consistent with the previous section, the grazing of stock was regarded as having the highest impact of all farming activities, with spray drift (18% (3)) and nutrient (12% (2)) effects from cropping activities also regarded as direct impacts of farm operations. An equally strong response from 35% (6) of respondents was that they believed their farm operations had no detrimental impacts on remnant native vegetation on their properties.

Table 21: Farming impacts on remnants

Impact	Number of responses	% of landowners
Stock grazing	6	35%
Spray drift	3	18%
Nutrients	2	12%
Weeds	1	6%
High kangaroo numbers	1	6%
Nil	6	35%

About a quarter of respondents indicated they had the ability to reduce these agricultural impacts, mainly (24% (4)) by constructing fencing around remnant vegetation. Of the seven respondents to the question, two indicated they did not have the ability to change their management activities as shelter for livestock was required and the cost of fencing was prohibitive.

Thirty five per cent (6) of landholders considered that high numbers of western grey kangaroos have a significant impact on their agricultural enterprise. Other impacts considered to be significant and attributable to remnant vegetation were parrots by 18% (3), rabbits by 18% (3), insects by 12% (2), foxes by 12% (2), and moisture competition by 12% (2).

Table 22: Farming impacts from remnants

Impact	Number of responses	% of landowners
Kangaroo grazing	6	35%
Rabbits	3	18%
Parrots	3	18%
Moisture competition	2	12%
Foxes	2	12%
Insects	2	12%

Nature Reserves Values, Threats and Management Issues

Values

All respondents indicated that the nature reserves are important and need to be conserved and managed to ensure they remain healthy. Conservation of fauna was considered the most important role of nature reserves by 71% (12) of respondents along with conservation of flora (29% (5)). Other environmental values identified by respondents were biodiversity (18% (3)), representativeness (12% (2)), and general conservation (6% (1)). Amelioration of land degradation was also thought to be a significant value by 12% (2) of respondents who considered that nature reserves contribute to recharge control through water usage and other soil conservation matters. One landowner regarded nature reserves as a source of seed for revegetation. Respondents also attributed landscape values, such as aesthetics (18% (3)) and wildflowers (6% (1)), to nature reserves.

Table 23: Landowner values of nature reserves

Value	Number of responses	% of landowners
Conservation of fauna	12	71%
Conservation of flora	5	29%
Aesthetic	3	18%
Biodiversity	3	18%
Climatic influence	2	12%
Water usage	2	12%
Soil conservation	2	12%
Representativeness	2	12%
Wildflowers	1	6%
Seed source	1	6%
Conservation	1	6%

Use of Nature Reserves

A majority (59% (10)) of landowners said that they bushwalk in the nature reserves. However, this varied from regular to very infrequent visits, and included wildflower spotting to casual bird watching. Traditionally, picnics had been popular, but only two respondents mentioned picnicking as a current activity.

A significant portion of the people in the project area (35% (6)) do not use the nature reserves in any way.

Respondents stated that the main use of nature reserves by people living outside the project area was illegal hunting (29% (5)) which was occurring in some reserves on a semi regular basis. Three (18%) landowners were aware of individuals who visited the reserves to see wildflowers, and two (12%) noted that commercial wildflower tours had also occurred. A Narrogin based nature group is also known to visit the reserves.

Threats

Weeds, introduced vermin and the high numbers of some native fauna species were regarded as the main threatening processes affecting the long-term survival of the nature reserves. Predators, such as foxes and cats, were the most commonly recognised threat being listed by 35% of respondents. Destruction by wildfire was also considered a serious threat by 24% (4) of landholders along with invasion by weeds. The grazing pressure of rabbits (18% (3)), parrots (18% (3)) and kangaroos (12% (2)) were thought to be a significant threat to the reserves. Other threats identified included senescence, native title, salinity, disease, illegal use and surrounding land use.

Current Problems

Landowners listed the major problems with the management of nature reserves as: lack of fire break maintenance (18% (3)); fox predation (18% (3)); and excess grazing by kangaroos (18%(3)), rabbits (18%(3)), and weeds (18% (3)). Other problems listed included erosion, fire management, cats, lack of management and an imbalance of native species.

Table 24: Threats to nature reserves

Threat	Number of responses	% of landowners
Foxes	5	35%
Grass/weed Invasion	4	24%
Wildfire	4	24%
Parrots	3	18%
Rabbits	3	18%
Kangaroos	2	12%
Cats	1	6%
Salinity	1	6%
Senescence	1	6%
Native title	1	6%
Disease	1	6%
Illegal use	1	6%
Surrounding land use eg spray drift, weed & nutrient importation.	1	6%

Improvements to CALM Management

The most common suggestion by respondents related to fire break maintenance by 35% (6) followed by the suggestion to extend the current fox baiting programs to all reserves by 24% (4). There was a suggestion to restrict vehicular access to reduce track erosion by 12% (2) and it was thought by various respondents that CALM should control burn, carry out weed control, provide an electric fencing subsidy and improve the balance of native species

Table 25: Suggested CALM management improvements

Management area	Number of responses	% of landowners
Fire break maintenance	6	35%
Extend fox baiting	4	24%
Weed control	4	24%
Track erosion/restrict vehicles	2	12%
Control burn	1	6%
Improve balance of native species	1	6%
Electric fence subsidy	1	6%

Agricultural Impacts Resulting From Nature Reserves.

Most of the impacts related to nature reserves resulted from the ability of some animals, both native and exotic, to use both agricultural and reserve land. Kangaroos were regarded as the most significant impact emanating from nature reserves with 65% (11) of landowners including them in their response. Foxes were also regarded as an impact by eight (47%) respondents along with rabbits (35% (6)) and parrots (29% (5)). Other impacts mentioned were wedge-tailed eagles (lamb predation) and moisture competition near reserve boundaries.

Table 26: Agricultural impacts from nature reserves

Impact	Number of responses	% of landowners
Kangaroo grazing	11	65%
Foxes	8	47%
Rabbits	6	35%
Parrots	5	29%
Moisture competition	1	6%
Wedge-tailed Eagles	1	6%

Revegetation Achievements and Future Intentions

Revegetation Requirements

Of the seventeen landowners surveyed, sixteen indicated that they required revegetation on their properties. The remaining landholder considered that all revegetation activities had been completed for their property. Land degradation issues were the main motivation for revegetating farmland with windbreaks to control erosion impacts on the landscape, mentioned by 47% (8), as the single most common reason given, along with water use for recharge control by 12% (2). Revegetating fence lines (17% (3)) and creeklines (12% (2)) for nature conservation corridors and improving aesthetics were also said to be important factors. Most farmers considered economic factors to be of low importance as a reason for revegetating. Shelter (12% (2)) and economic returns (6% (1)) were also given as reasons for revegetation.

Table 27: Landowner revegetation requirements

Type of revegetation responses	Number of required	% of landowners
Windbreaks	8	47%
Aesthetics	3	18%
Corridors	2	18%
Creeklines	2	18%
Erosion control	2	18%
Shelter (stock)	1	6%
Water use	1	6%
Economics	1	6%
Nil	1	6%

Revegetation Activities

A majority of landowners (15) indicated they had previously conducted revegetation activities on their properties. The use of tagasaste for fodder and erosion control by 35% (6) was the most common form of revegetation previously undertaken. Pines had also been planted by 30 % (5) of respondents for erosion control on sandy soils, but it was indicated these were no longer favoured as an option due to their perceived lack of environmental benefit. Native plantings, which included the use of mixed eucalyptus (24% (4)), mixed natives (29% (5)) and local mixed natives (29% (5)) for corridors, windbreaks and aesthetic reasons were also widespread uses of revegetation. Oil mallees had also been planted by two respondents who were hoping for an economic return and saw them as a useful species for alley farming.

Position in Landscape

There was no dominant part of the landscape that had been previously planted. The only general pattern is that revegetation has not been used in a way that utilises any land that is considered productive for agriculture. Areas previously planted included fencelines by 24% (4), creeklines by 24% (4), sandy erosive soils by 24% (4) and varied positions on the farming landscape by 24% (4). The north and west of paddocks were considered important positions by 12% (2) of respondents for revegetation as this provided the best protection against the strongest winds, and thus wind erosion. Rocky areas, such as ridges, breakaways, and ironstone outcrops, were also regarded by 18% (3) of respondents as a preferred area for revegetation.

Barriers To Revegetation

The cost of establishment (including fencing) was regarded as the main barrier to carrying out revegetation by 47% (8) of respondents. Having time available to implement revegetation works was also considered to be a significant barrier by 29% (5). The loss of productive land required to revegetate was seen as a secondary barrier by 18% (3) along with grazing by rabbits by 6% (1).

Table 28: Barriers to landowner revegetation activities

Barrier	Number of responses	% of landowners
Cost	8	47%
Time	5	29%
Lost production/land availability	3	18%
Rabbits	1	6%

Preference For Local Species

A majority of landowners (53% (9)) expressed a preference for using local species for revegetation for reasons varying from their ability to successfully grow in the landscape to their local aesthetic appeal. While other respondents (35%) indicated they may prefer local species, their final selection depended on a range of factors including: altered soil conditions, economic considerations and the specific purpose of revegetation and the suitability of local species to fulfil that purpose. Two respondents indicated they had no preference for what species they used.

Interest In Commercial Local Species

It was explained to landowners that prospective commercial local species were native plant species found in the Wheatbelt that, if markets were developed, have the potential to generate an economic return, for example, brown mallet and sandalwood. Landowners were asked if they were interested in using such species when revegetating. Sixty five percent (11) indicated an interest while 35% indicated they had no interest in such species.

Source Of Revegetation Advice

CALM was the most common source of revegetation advice listed by respondents with 41%

(7) indicating they had used the Department in the past. LCDC or catchment group coordinators were also popular sources of advice for 29% (4), along with Dongolocking Corridors Project Coordinator, Terri Lloyd 29% (4). Other sources of advice listed include: AgWA by 18% (3), private nurseries by 12% (2), and Oil Mallee Association workers by 6% (1). Some respondents listed multiple sources of advice which included more than one of the above.

Table 29: Source of revegetation advice

Source	Number of responses	% of landowners
CALM	7	41%
LCDC/Catchment group	5	29%
Terri Lloyd	4	24%
Private nurseries	2	12%
Neighbours/observations	2	12%

Catchment Group Membership

A majority of landowners (65% (11)) indicated they were currently members of a catchment group though this varied from a strong involvement through to an irregular association. Thirty five percent indicated they were not connected with a catchment group.

Information/Plan Requirements

Content of Information Required

Landowners were asked if they required any specific information to assist them in managing their remnant vegetation or to carry out revegetation activities. Of those that wanted information it was stressed that it had to be practical and in a useable form, that is, reports that sat on the shelf were of little value. Advice on successful revegetation was the main information requested by 41% (7) of landowners and this ranged from species selection, commercial options, and site evaluation. Other information requested included advice on fire management in remnants, fauna survey techniques, and weed control methods in remnants. Three landowners indicated that they required no further information.

Table 30: Revegetation/remnant management information required

Information type	Number of responses	% of landowners
Revegetation	7	41%
Fire management in remnants	1	6%
Fauna survey techniques	1	6%
Weed control in remnants	1	6%
Nil	3	18%

Format of Information Delivered

All the landowners requiring information requested that information be accessible and in a format they can readily understand. The production of leaflets or newsletters was the most requested format (59% (10)) along with meetings and field days by 29% (5). Three farmers stressed the importance of using existing information channels such as LCDCs or catchment groups rather than creating a new structure.

Table 31: Information Presentation Format Required

Information format	Number of responses	% of landowners
Leaflets/newsletters	10	59%
Meetings	5	29%
Field days	5	29%
Via existing groups ie. LCDCs/catchment groups	3	18%

THREATS TO CURRENT LAND USE

by Ken J. Wallace

The goal of this project centres on nature conservation. Given that achieving this goal is dependent on developing sustainable agriculture, this section focuses on threats to nature conservation and agriculture.

Other land uses within the project area include:

a) recreation (small numbers, low frequency) and other cultural use of remnant vegetation;
b) recreation on farm dams (landholders and their guests);
c) aquaculture (yabbie farming); and
d) transport, water, power and communications infrastructure.

Of these, (a) is considered briefly, and (b) and (c) are picked up as part of on-farm water conservation which will be dealt with during Phase II. Category (d), infrastructure, is outside the project brief and is not considered.

As explained in "Land Management at the Landscape Scale - a Framework" and "Nature Conservation at the Landscape Scale - a Framework", threats to land use goals identify problems in environmental cycles and processes, at least in terms of specified goals. On this basis, it would be logical to categorise threats within key environmental processes and cycles. This was attempted during the project, but proved unfruitful because:

- Single activities, such as stock grazing of remnant vegetation, interfere with a range of cycles and processes including nutrient cycling, reproduction and water cycling (see Table 33, page 58). Therefore tabulations and categories become too diffuse to be of value to managers; and
- The categories that evolve are not of immediate, obvious relevance to managers.

Consequently, categories were not classified under various environmental processes. However, the linkage to processes is important, and a matrix is provided at the end of this section to highlight the relationships between various threats and environmental processes and cycles. Of the many other ways in which threats may be grouped and described, that used here is specifically structured to help land managers identify those issues they must deal with as a matter of priority.

Before describing the various threats, one further matter must be dealt with. This is that, while threats within the study area are the main focus of this work, the Dongolocking project area is part of a larger system of land uses that must be taken into consideration. For example, some drainage from the Dongolocking area eventually enters Dumbleyung Lake, an area of local importance for recreation. Water quality is an issue for the Lake as increasing salinity and more frequent micro-organism "blooms" threaten recreation activities and wildlife.

Furthermore, water, salt and other substances exported from the study area affect downstream agriculture. Thus agricultural practice and management of remnant vegetation at Dongolocking affect downstream recreation activities, conservation and agricultural land use. Therefore any consideration of threats must also recognise these wider issues. Threats relevant to this project are therefore grouped below by land use, and by whether impacts are within or outside the study area. To help the reader, the structure of the remainder of this section is summarised in Table 32 below.

Table 32: Grouping of threats

Threats Within the Study Area

- *Threats to nature conservation (or conservation of natural biodiversity)*
- *Threats to agricultural land use - land conservation*
- *Threats to agricultural land use - water conservation*
- *Recreation and tourism on remnant vegetation*

Threats Posed by Land Use in the Study Area to the Region

- *Threats to nature conservation*
- *Threats to agricultural land use*
- *Threats to recreational activities*
- *Threats to infrastructure*
- *Threats to potable water*

Threats Within the Study Area

Threats to Nature Conservation (or conservation of natural biodiversity)

Threats that must be managed to conserve natural biodiversity within the study area are listed below. Most of these threats are managed at two levels - that of the individual remnant, and at the landscape or regional level. Threats interact in a variety of ways, and often produce impacts that are compounding rather than accumulative. They are also sometimes, but rarely, antagonistic (for example, foxes eat rabbits). The positive aspect of compounding interactions between threats is that judicious management will meet several objectives at the same time. The downside is that management is very complex, and our knowledge of the relevant processes is poor. In those cases where threats are antagonistic, then controlling one may release the other. For example, controlling the fox, a damaging predator of fauna, may cause an explosion in rabbit numbers with detrimental effects on native flora.

The categories of threats listed below are comprehensive, but not the issues provided as examples.

1. Clearing and fragmentation of native vegetation: Issues include:

a) creating sufficient habitat types and space for viable populations of plants and animals to persist. This includes sufficient space for habitat replication so that disturbance regimes, see (b) below, may be managed. Clark *et al.* (1990) list many of the relevant population parameters under their "biological considerations" column (see Figure 3). However, note that this table is incomplete. For example, it does not clearly list the important plant population processes of pollination and dispersal methods;
b) managing, as far as practicable, disturbance regimes - that is, disturbance events such as fire, natural disease, windstorms, etc. must occur often enough to create space for early seral stages and species favoured by them without being either too frequent, or combined in a way that results in local extinctions; and
c) reducing the impact of edge effects, such as fertiliser and pesticide drift into remnants.

Buffers, corridors, reconstruction, and regeneration of degraded areas are important management techniques in this context. The key is to implement actions that increase the amount of habitat for species, particularly those that are vulnerable or provide important ecosystem services.

2. Disruption of biogeochemical processes: Issues include managing:

a) hydrological processes, particularly in relation to salinity and negative impacts of drainage;
b) nutrient cycles, including eutrophication and nutrient impacts of agriculture on remnants; and
c) the carbon cycle and climate change.

3. Competition, predation and other impacts of introduced species: Issues include:

a) weed control;
b) control of feral predators;
c) prevention of new introductions of damaging species; and
d) grazing and trampling of remnants by stock.

4. Damage from problem native species: Issues include:

a) explosion 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.

5. Disease: Issues include:

a) dieback (*Phytophthora* spp); and
b) armillaria.

6. Inappropriate use of pesticides: Issues include:

a) herbicide use and direct impacts on plants, including effects of fungicides; and
b) pesticide surfactants and impacts on vertebrate reproduction.

7. Competing land uses. Issues include:

a) recreation management;
b) farm management;
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. Current culture: Issues include:

a) attitudes to conservation;
b) poor understanding of nature conservation values and their vital contribution to human quality of life; and
c) improving level of remnant vegetation protection through changes of tenure (for example, purchase of private land and inclusion into conservation estate).

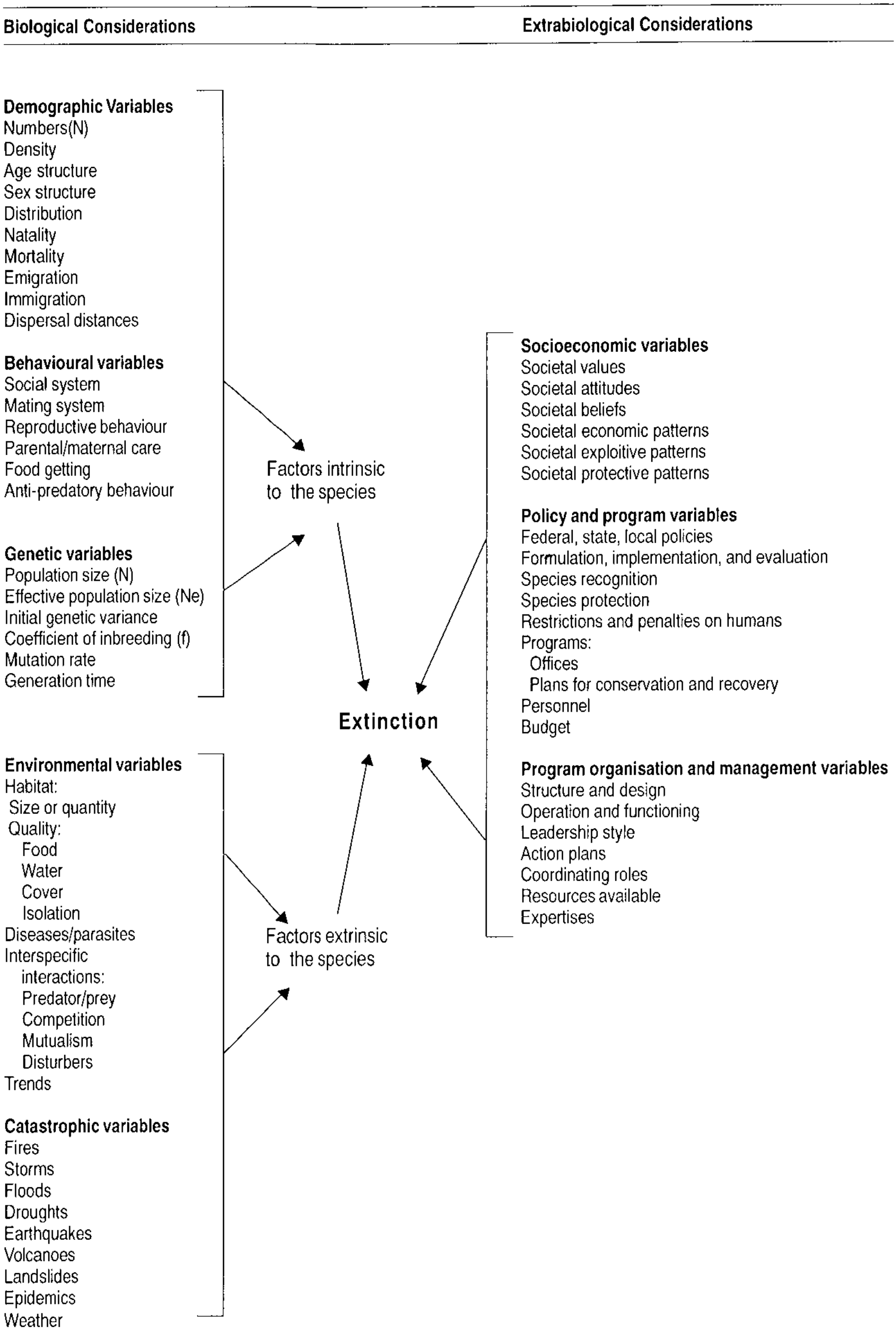


Figure 3: Biological and extrabiological factors that can cause extinctions (from Clark 1989, as used in Clark *et al.* 1990)

9. Loss of rare species, endangered communities, and species sensitive to the above threats: This category is a result of one or more of the above, and is not a threat in the same sense as (1) to (8). It is listed here given the importance accorded to management of these groups, and the need for managers of natural land to take them into consideration.

All of the above issues are important in this project. Their management is dealt with either in "Nature Conservation at the Remnant Scale", "Nature Conservation at the Landscape Scale - Adequacy of Habitat"or "Nature Conservation at the Landscape Scale - Other Factors".

Threats to Agricultural Land Use - Land Conservation

Threats that must be managed to conserve agricultural land include:

1. Salinity. Issue is that replacement of perennial native vegetation with annual crops and pastures has led to a new, dynamic hydrological system that has significantly increased re-charge to groundwater systems with consequent rise of saline groundwater. Fundamentally, solutions relate to either using water where it falls (decreasing recharge), shifting water somewhere else, or a combination of these. While the last is a solution favoured by many land managers, shifting water always raises questions about off-site impacts. This issue will be considered in phase II of the project.

2. Waterlogging. Issues include:
a) loss of macropores;
b) soil compaction and water repellence; and
c) loss of perennial cover.

Solutions and issues are similar to those listed for (1), but the impacts of shifting surface water are generally less than those resulting from draining groundwater. This issue will be considered in phase II of the project.

3. Soil structure decline
Solutions for this threat, apart from structural decline related to increasing salinity, do not interact significantly with nature conservation. However, this threat will receive some attention in phase II of the project.

4. Soil compaction
As for (3).

5. Soil acidity
As for (3).

6. Water erosion
This threat will be considered briefly during phase II of the project.

7. Water repellence
As for (3).

8. Wind erosion
Farmers in the study area perceive this threat as the most significant. It will be dealt with in phase II of the project.

9. Cultural and economic barriers to sustainable land use
a) cultural changes are required to achieve sustainable agriculture, this involves a range of social and political issues; and
b) profitability of agriculture must be adequate to support necessary changes.

Only (b) will be considered in this project, during phase II.

Threats to Agricultural Land Use - Water Conservation

Issues dealt with here will relate not only to agriculture, but also to on-farm water recreation and aquaculture. Threats that must be managed to conserve water include:

1. Salinity.

2. Siltation.

3. Excessive loss of nutrients to water bodies.

4. Contamination, biological or chemical.

5. Cultural barriers - see item (9) in the previous section.

All these threats also affect wetlands set aside for nature conservation. Although there are no wetlands within the study area, drainage from Dongolocking affects nature reserves downstream. This set of issues is considered in phase II of the project.

Recreation and Tourism on Remnant Vegetation

This issue will be considered only briefly. Threats include:

1. *Loss of nature conservation, farming, heritage and other values on which recreation and tourism are based.*

2. *Loss of local landscape's identity.*

3. *Ineffective marketing and communication of recreation and tourism opportunities.*

4. *Inadequate development of a local culture and the professionalism essential to success in commercial recreation and tourism.*

5. *Failure to provide the facilities and support necessary for success.*

Of the above, only (1) and (2) are relevant to this project. They are briefly considered in both parts of the project.

Threats Posed by Land Use in the Study Area to the Region

These threats consist of exported materials. Topics relevant to this category include exports of:

a) water (either too little or too much);

b) substances in water (such as salt, pesticides and excess nutrients);

c) exports by wind, such as dust and chemicals; and

d) weeds, diseases and exotic animals to areas where they are not present.

There are no plants or animals in category (d) living within the study area that are not already found in adjoining regions. However, export of problem plants and animals should be prevented or minimised. This is not an issue that will be dealt with during this project. Also, while (c) may be an issue, it is not of sufficient importance as an export to be considered further here.

Points (a) and (b) are relevant to this project, particularly phase II. Specific issues are listed below, and will be dealt with in the project where appropriate.

Disposal of water downstream poses the following potential threats:

Threats to Nature Conservation

1. Significant changes to water volumes

a) inappropriate hydroperiod (either too little or too much water) affecting waterbirds (for example, breeding or feeding), seedling recruitment, vegetation maintenance (for example, flooding causing death), nutrient transformations, etc. This category is very large, and may lead to complete changes in ecosystems;
b) increased artificial flooding of natural wetlands decreases their ability to act in flood mitigation.
c) may increase water erosion; and
d) increased artificial flooding of natural wetlands may affect their role as (when dry) important discharge areas that protect adjoining lands. It may also lead to increased recharge.

2. Increasing silt

a) impedes drainage;
b) fills and degrades or destroys pool habitats;
c) may enhance erosion;
d) carries chemicals that detrimentally affect biota;
e) impedes evaporation-discharge; and
f) increases turbidity which may compound other threats.

3. Increasing salt

a) results in vegetation communities shifting to those composed of salt tolerant species, and in worst scenarios, reduces vegetated areas to salt scalds;
b) results in fauna and micro-organisms community composition changes to those species that are able to tolerate saline or hyper-saline environments; and
c) consequences of (a) and (b) include loss of biodiversity values and nutrient cycling functions.

4. Increasing levels of nutrients

a) changes vegetation types;
b) composition of fauna and micro-organism communities change to those species that are able to tolerate nutrient rich environments; and
c) consequences of (a) and (b) include loss of biodiversity values and, potentially, eutrophication.

Threats to Agricultural Land Use

All of the changes listed in the preceding section may also detrimentally affect agricultural land use. Impacts are on water points, drainage lines, aquaculture and water quality for stock and other uses.

Threats to Recreational Activities

1. Increasing silt

a) turbidity affects water aesthetics; and

b) boating and other recreational sites directly affected in relation to access or aesthetics (for example, sand converted to mud).

2. Increasing salt

a) affects water quality for swimming, water skiing, etc; and

b) degrades aesthetics of the recreation environment.

3. Increasing nutrients

a) nutrient excesses may lead to undesirable odours; and

b) "blooms" may be toxic.

Threats to Infrastructure

Many of the items listed for nature conservation may affect infrastructure. For example, increased salinity and flooding will threaten downstream infrastructure such as roads and towns. Infrastructure is not dealt with in this project.

Threats to Potable Water

Silt, nutrients and salinity may all threaten downstream water resources (stock or domestic). Only stock water is dealt with in this project (phase II).

Concluding Comments

At the beginning of this section, the usefulness, but difficulty, of grouping threats according to environmental processes and cycles was discussed. In concluding this section, it is valuable to describe the interrelationships between a sample of the specific threats listed above and a selection of environmental processes and cycles. Table 33 is not comprehensive, but it does illustrate the complex outcomes from a single management step, such as introducing a feral animal, or grazing domestic stock.

This table underlines the dangers of introducing new biotic elements into ecosystems, and the potential for broad impacts on environmental processes. At a descriptive level, the difficulty of using cycles and processes directly as a means of organising management categories is also clear.

Table 33: Relationships between selected threats and environmental processes

Threat	Selected Processes and Cycles			
	Hydrological cycle	Nutrient cycle	Reproduction processes	Erosion processes
Salinity	✓	✓	✓	✓
Soil compaction	✓	✓	✓	✓
Predation		✓	✓	
Stock grazing	✓	✓	✓	✓
Exotic fungal disease	✓	✓	✓	✓

✓ *= threat affects cycle/process*

NATURE CONSERVATION AT THE LANDSCAPE SCALE – ADEQUACY OF HABITAT

by Robert J. Lambeck

Introduction

Background

As discussed in "Nature Conservation at the Landscape Scale - a Framework" management for nature conservation at the landscape scale generally involves:

- provision of adequate habitat patches to maintain viable local populations;
- provision for recolonisation;
- direct management of threats; and
- management of particular species (usually threatened or commercial species) and communities.

This section deals primarily with the first of these requirements, the provision of adequate habitat, and also provides recommendations for corridors which are applicable to the second requirement, provision for recolonisation. Strategies to deal with the direct management of threats are either covered elsewhere in this report (see "Nature Conservation at the Landscape Scale - Other Factors") or, in the case of threatened and commercial species, by existing CALM policies and strategies.

In this report the term "adequate habitat" describes the amount and type of habitat required to ensure that the persistence of a breeding unit (which may be a breeding pair or family group) within the study area is not threatened by lack of:

- food;
- water;
- shelter; or
- mates (for example, if one of a mating pair dies, then connectivity must allow a new mate to be found) and other reproductive services (such as pollination) required for reproductive success.

These resources must be sufficiently abundant that the individuals present can survive minor local disturbances (small fires, local windstorms, etc.), or, if they are unable to persist, that other individuals of the same species are able to recolonise from elsewhere.

To estimate adequate habitat it is assumed that the pressure from other threats - such as competition from exotic plants and animals and loss of land to salinity - are constant or declining. The management strategies for achieving a constant or declining pressure from these other threats are described in "Nature Conservation at the Landscape Scale - Other Factors" and "Nature Conservation at the Remnant Scale".

The approach presented in this chapter specifies adequate habitat for ensuring that breeding units of native plants and animals at Dongolocking have an 80% probability of persisting over the next 50 years. Ideally, this aim would be couched in terms of long-term (100 years or more) population viability rather than persistence of a breeding unit. However, this is not achievable given the:

- lack of information on viable population numbers for individual species; and
- lack of resources to explore population viability within the Dongolocking area during this study.

The issue of population viability is considered in more detail on pages 72 and 73.

Focal Species Approach

The method adopted to determine adequate habitat is based on the focal species approach (Lambeck 1997). The steps in this approach, as adapted for use at Dongolocking, can be summarised as follows:

1. describe the range of threats to be managed. In this particular section, we are dealing with the threats posed by a lack of food, water, shelter, mates and other reproductive services, and sufficient resources to survive minor local disturbances. Other threats are dealt with in "Nature Conservation at the Landscape Scale - other Factors" and "Nature Conservation at the Remnant Scale".
2. for each threat listed in (1), identify the species that are known (or suspected) to be declining as a result of that threat. In the Dongolocking case study the threats listed under (1) are treated as a single threat that may be accommodated by ensuring there is adequate habitat - a combination of habitat type and area.

3. rank species according to their sensitivity to the threats. The species most sensitive to each threat is called a focal species.
4. develop a management response to the threats based on the needs of focal species.
5. design and implement monitoring procedures that measure the success or failure of those management responses.

The application of steps (2) to (5) is described below.

Species at Risk - Potential Focal Species

Ideally, a detailed biological survey would be undertaken to identify species most threatened by lack of adequate habitat. Such surveys would be designed to detect declines in the distribution and/ or abundance of any plants or animals. Unfortunately, such surveys are rarely feasible. In this project vulnerable species were identified by:

- reviewing existing literature;
- consulting relevant experts;
- strategic surveys of remnant vegetation; and
- drawing on experience from other parts of the agricultural zone.

Major biological groups from which focal species might be drawn are discussed below.

Birds

Work undertaken elsewhere suggests that at least 30 bird species which occur in the Dongolocking area are decreasing in numbers throughout the agricultural region (see Table 8, page 32). On the basis of surveys conducted during the current study a total of 35 species were sufficiently poorly represented that they should be considered potentially vulnerable (Table 34, below). Species were considered vulnerable if they were found on less than 20% of the surveyed remnants that contained suitable habitat. Farm birds, migratory species, vagrants, and species at the margin of their natural distribution were not included.

Each of the birds listed below is considered a potential focal species, and they formed the basis for the focal species approach in this study.

Mammals

Small to medium-sized mammals have undergone a significant decline in both distribution and abundance in the agricultural regions of Western Australia. Thirteen species of terrestrial mammal have become locally extinct. One of these, the quenda or southern brown bandicoot (*Isoodon obesulus fusciventer*), has since been reintroduced to Dongolocking Nature Reserve. Of the remaining mammal species, five could be considered to be at risk. These are listed in Table 35.

Table 34: Bird species considered potentially vulnerable in the Dongolocking area

Species	% of remnants occupied	Species	% of remnants occupied
Dusky woodswallow	19	Purple-gaped honeyeater	4
White-eared honeyeater	18	Bush stone curlew	1
Jacky winter	17	Red-capped parrot	1
Restless flycatcher	17	Owlet nightjar	1
White-browed scrub wren	17	Hooded robin	1
Golden whistler	15	Striated field wren	1
White-cheeked honeyeater	15	Australian hobby	0*
Silvereye	14	Crested shrike-tit	0
Regent parrot	13	Little wattlebird	0
Tawny-crowned honeyeater	13	Long-billed black-cockatoo	0
Western rosella	11	Malleefowl	0
Brown goshawk	8	Mistletoebird	0
Shy hylacola	8	New Holland honeyeater	0
Western thornbill	7	Scarlet robin	0
Southern scrub robin	6	Southern emu-wren	0
Western yellow robin	6	Spotted pardalote	0
Peregrine falcon	4	Western spinebill	0
Blue-breasted wren	4		

* *Birds with a "0" score have been recorded at Dongolocking, but were not seen during survey work for this project (see Table 9, page 43).*

Table 35: **Mammal species potentially at risk in the Dongolocking area**

Western Brush Wallaby	*Macropus irma*
Brush-tailed Possum	*Trichosurus vulpecula*
Quenda	*Isoodon obesulus fusciventer*
Red-tailed Phascogale	*Phascogale calura*
Honey Possum	*Tarsipes rostratus*

While these mammals could be used as focal species to evaluate and manage the threat of fox and cat predation, this predation pressure is so high that until it is eased the threat to mammals of inadequate habitat cannot be assessed. Therefore, although the quenda is used as a focal species for assessing fox predation, none of the mammals may at present be used for assessing adequate habitat.

Once predation is sufficiently controlled, it is possible that some mammals will be used for assessing adequacy of habitat. In particular, there is an important question concerning the adequacy of habitat for the western brush wallaby.

Reptiles and Amphibians

Little information is available to assess the status of any species from these groups. Most species of frogs will be sensitive to increasing levels of salt in the soil and in streams and dams, but they are a difficult group to survey. Members from either of these groups would be difficult to use as focal species given currently available information, although an ongoing study into the population dynamics of the reticulated gecko in the central wheatbelt (Sarre, Smith and Meyers 1995; Sarre 1995) suggests that this species is habitat limited. If the work at Dongolocking expands, it is planned to research whether reptiles may be effectively used as focal species for adequate habitat.

Invertebrates

Virtually no information is available to assess the status of invertebrates in the district. Work elsewhere in the wheatbelt suggests that predatory species such as mygalomorph spiders (Main 1987) and some scorpions (Smith 1995) are most likely to be at risk due to inadequate habitat. There is insufficient information to use any members from these groups as focal species at Dongolocking.

Plants

Vulnerable communities: Plant communities that occur in the low-lying parts of the study area will be most vulnerable to salinity. These are predominantly woodland communities such as York gum, salmon gum and morrel woodlands. Many private remnants containing these vegetation types are also at risk from stock grazing and weed invasion. In the short-term, weeds and salinity, rather than adequate habitat, are likely to be the major threat to persistence of most threatened communities at Dongolocking. Salinity and weeds as threats are discussed in "Nature Conservation at the Landscape Scale - Other Factors". However, if research continues at Dongolocking, it is planned to explore in more detail whether there are plant communities threatened by inadequate habitat.

Vulnerable plant species: Plant species within the study area considered by CALM to be rare, threatened or locally significant are listed in Table 36 (page 62). The Department also maintains a list of plant species that are poorly known. This list is used to determine priorities for surveys and monitoring, and provides a basis for establishing conservation status.

Although threatened plant species in the Dongolocking area could be used as focal species, none are known to be threatened by inadequate habitat, and critically endangered species are covered under CALM management processes. Therefore, none were considered as focal species for adequacy of habitat in this work.

Conclusions on Focal Species at Dongolocking

The requirements of birds were considered most suited for specifying the minimum acceptable area for each patch (habitat) type. Mammals were not considered to be limited by the amount of habitat available in the current landscape. This is because they are primarily vulnerable to predation by foxes and cats, and until this threat is managed, adequacy of habitat cannot be assessed. Reptiles appear most susceptible to habitat loss and degradation (for example, How and Dell 1994, Smith *et al.* 1996), but are also affected by predation. Invertebrates are influenced primarily by changes to their microhabitat caused by grazing and weed invasion. Plants also appear to be mostly affected by grazing, salinity and weeds, and, in some cases, may be sensitive to inappropriate fire regimes. In addition, the most threatened species are already managed by CALM, and actual habitat is not an immediate issue. On this basis, we concluded that the habitat requirements of birds are most suited for specifying landscape designs to provide adequate habitat. All other groups of organisms are considered, in the short term, to have a primary requirement for improved management of the patches that currently exist in the landscape.

Table 36: Rare, threatened or locally significant flora that have been recorded within the study area

Species and Status	Habitat
Declared Rare Flora	
Lechenaultia pulvinaris	Deep white sands high in landscape.
Calectasia arnoldii ms	Heath-shrublands on white-yellow sand over laterite.
Priority 1	
Conospermum scaposum	May occur on alluvium and colluvium; not recorded but likely to occur.
Priority 2	
Andersonia carinata	Mixed tall shrubland on alluvial and colluvial soils on gently undulating, seasonally wet plains.
Microcorys tenuifolia	Heath of *Dryandra armata*, *Melaleuca pungens* and *Hakea* spp. on colluvial soils.
Chamelaucium croxfordii ms	Open scrub and low open *E. wandoo* woodland on sandy loam, loamy sand, stony sandy clay and laterite.
Dryandra cynaroides	Low scrub and heath with other *Dryandra* spp. on sandy laterite gravel and sand.
Lasiopetalum cardiophyllum	Wandoo woodland over heath on sandy clay over clay soils on gentle slopes.
Priority 4	
Daviesia crassa	
Pomaderris bilocularis	
Other Significant Species	
Banksia grandis	
Eucalyptus macrocarpa	
Santalum spicatum	

If this argument can be sustained, it provides an effective tool for rapidly specifying the amount and placement of reconstructed habitat because of the relative ease with which estimates of bird presence or absence can be obtained in a short period of time. The assumption that landscape designs based on the needs of birds will also protect other species is one that clearly needs to be tested (see "Assumptions Made", page 73). Although birds appear to be the most appropriate focal species for designing habitat, a recent workshop to discuss the Dongolocking project concluded that, if research resources permit, the case for using reptiles, plants and some mammals should be re-examined.

Habitat Requirements for Focal Species – Patch Type and Patch Size

In relation to adequate habitat patches three questions were addressed in the work at Dongolocking:

1. What are the dominant habitat types that occur in the region?
2. What is the minimum patch size of suitable habitat needed to support a breeding unit of the birds selected as focal species? and
3. Are patches well enough connected to allow ready movement of birds between patches within the study area?

Answers to these questions provide the basis for calculating whether revegetation is necessary, and if so, what type of revegetation is most important. In this section the question of patch type is addressed, and then patch size is examined.

Patch Type

A detailed description of the vegetation in the Dongolocking area was presented in "Description of the Study Area". Because of the complexity of the vegetation in the area it was not possible to individually consider the use by birds of every patch type. Consequently, the following simplified set of vegetation types was used in the analysis:

1. Woodland;
1. Mallee;
2. Shrublands;
3. Heathlands; and
4. Lithic complex.

Recommendations for habitat reconstruction presented below are expressed in terms of these broad habitat types. The actual plant species used in any reconstruction should reflect the vegetation associations in habitat adjacent to the area where reconstruction is planned.

Patch Size

To determine the minimum patch sizes required by the focal bird species, surveys were undertaken to examine how these species were distributed throughout the landscape. These surveys enabled us to determine the characteristics of habitat patches that are able to support focal species as well as the characteristics of patches from which they are absent. Analysis of presence/absence data enables us to specify the minimum sizes of patches in which particular species occur, and the maximum levels of isolation beyond which particular species are not found. At Dongolocking, species presence or absence was assessed independently for each of the major habit patch types in the area. This enabled separate design specifications to be produced for each of these vegetation associations.

In the Dongolocking work, the original list of 35 potential focal species was reduced to 14 by excluding species that are:

- nocturnal;
- sensitive to predation by feral animals, such as the ground-nesting bush stone-curlew;
- known to have very large territories or area requirements, such as raptors;
- known from previous reports to occur in the area, but were not sighted in the current surveys; and
- regional nomads.

During survey work, the presence of a species in a remnant on two visits during the breeding season was interpreted as representing a breeding unit. This is considered a reasonable assumption given the time since isolation of most patches, although see Saunders *et al.* (1991). However, it would be desirable to test this assumption with more extensive field work over all seasons.

Patterns of patch use by the selected set of habitat-limited birds are shown in Figures 4-6. From these figures it is possible to determine patch sizes above which these species have a high probability of occurring. In this study, 60% probability of occupancy was used as the cut-off point. That is, the patch area above which 60% of patches were found to be occupied by focal species. The results of this analysis are shown in Table 37 (page 64).

These figures indicate that many of the selected bird species are less likely to occur in remnants with less habitat. Others, such as parrots, hooded robins and blue-breasted fairy-wrens do not show this trend, suggesting that habitat availability is not the primary factor limiting their abundance.

The obvious response to a shortage of habitat is to create more. In order to benefit the greatest number of species, patches of new habitat should be large enough to support those species that require the greatest patch area. Any patch that is large enough for these more demanding species should also be large enough to support all other species that use the same patch type. The creation of additional suitable patches can be achieved by enlarging existing patches or by creating new patches which exceed the minimum required dimensions. The first option is preferred as less mobile species of birds, as well as reptiles, invertebrates and plants, are more likely to colonise new habitat if it is next to existing patches.

Map 6 (page 67) indicates all areas adjacent to existing habitat patches that are currently too small for the most area-limited species. The expansion with revegetation of all areas indicated on Map 6 would create an additional 186 patches of woodland, 13 patches of shrubland and 21 patches of heath. This would provide a total of 7 509 ha of additional habitat. The fact that woodland habitat makes up most of the recommended revegetation reflects the fact that there are many small patches of woodland in the area and relatively few patches of shrubland and heath. There are currently only 3 patches of shrubland and 13 patches of heath that are large enough to support the most demanding shrubland and heath species.

The large number of woodland patches that have been identified as suitable for enlargement is a consequence of enhancing all patches greater than 2 ha in size. This level of reconstruction is likely to be excessive and unlikely to be implemented.

In order to reduce the proposed number of patches it is possible to select only larger patches for enhancement. Map 7 (page 68) shows the results of an equivalent analysis in which woodland remnants are enlarged only if they are greater than 5 ha in size. This solution would create 86 additional patches compared with the 186 created if patches as small as 2 ha were enlarged. The total area required under this new plan would only be

Table 37: Patch area required for area-limited bird species to have >60% probability of occupancy

Woodland	Area required (ha)	Shrubland	Area required (ha)	Heathland	Area required (ha)
White-eared honeyeater	>50	Western thornbill	>15	White-browed scrub wren	>15
Restless flycatcher	>50	Southern scrub robin	>15	White-cheeked honeyeater	>15
Jacky winter	>50	Purple-gaped honeyeater	Insufficient data	Tawny-crowned honeyeater	>15
Golden whistler	>50	Western yellow robin	Insufficient data	Shy hylacola	>15
				Western thornbill	>15
				Blue-breasted fairy wren	insufficient data

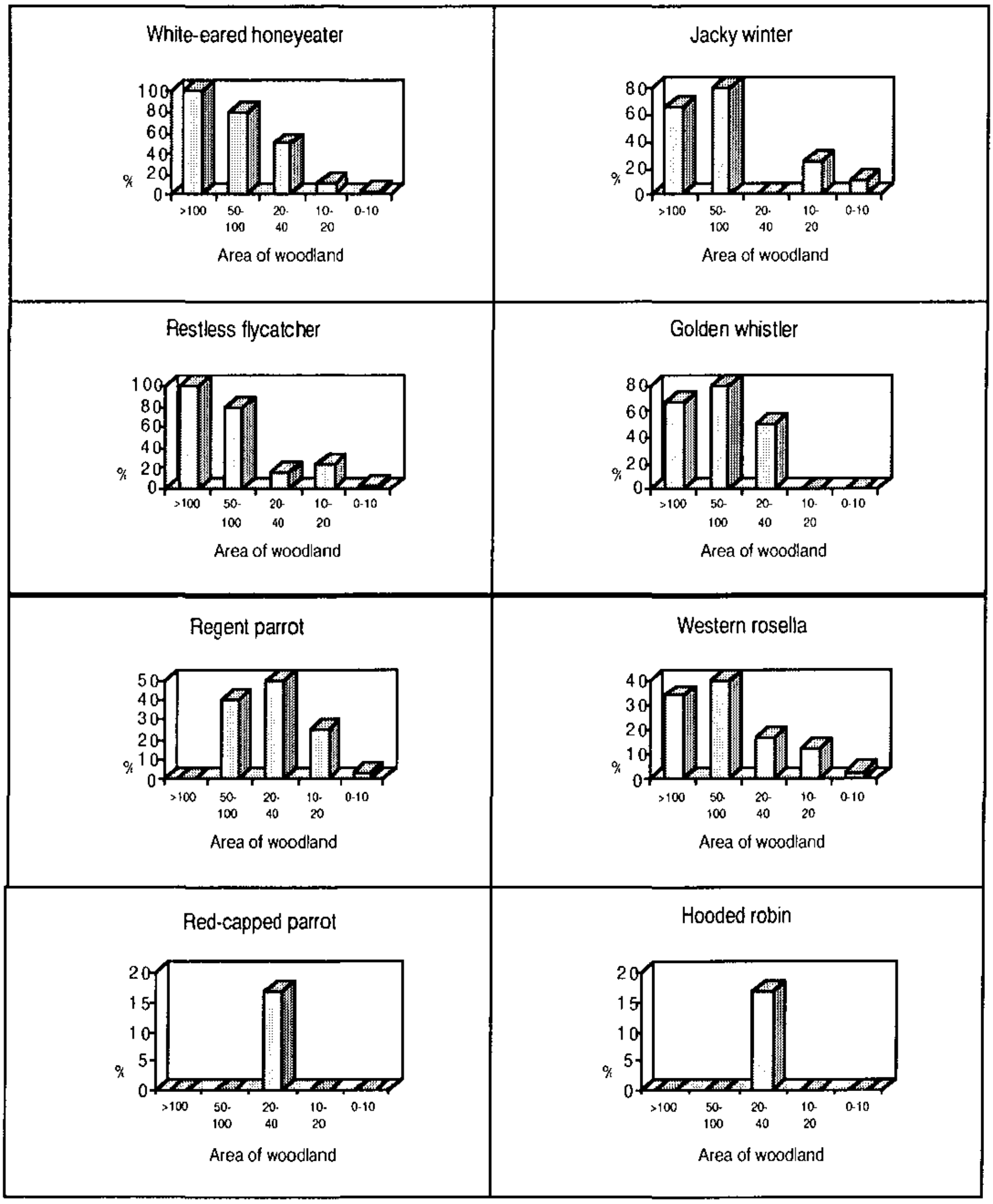


Figure 4: Patterns of patch occupancy by potentially vulnerable woodland birds. White-eared honeyeaters and golden whistlers appear to be most sensitive to the area of woodland in a remnant while the vulnerability of parrots and hooded robins does not appear to be caused by patch area

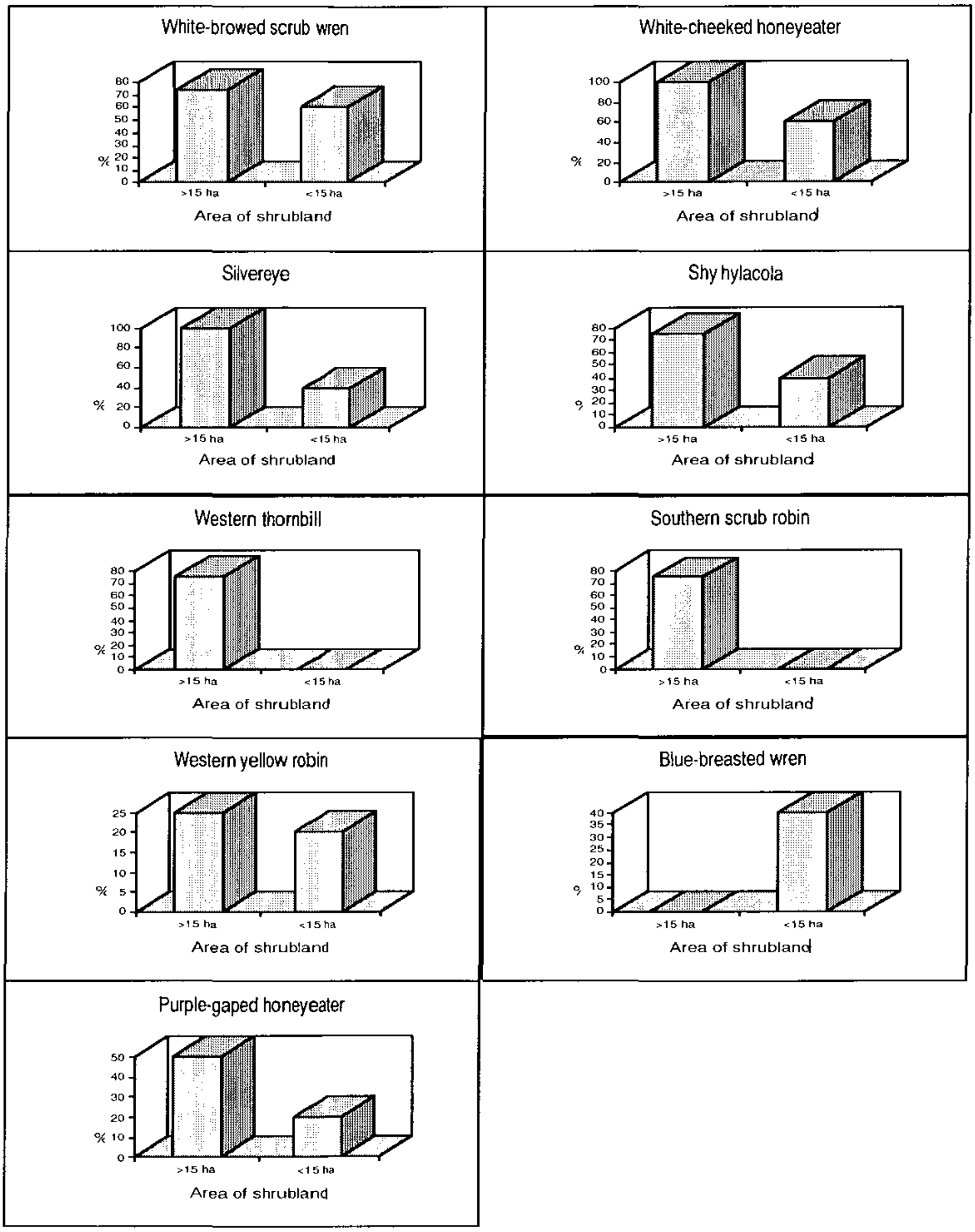


Figure 5: Patterns of patch occupancy of potentially vulnerable shrubland birds. Western thornbills and southern scrub robins appear to be most sensitive to the area of shrubland in a remnant. Due to the small number of shrubland patches in the area it was necessary to pool remnants into two size classes

3 026 ha instead of the 7 509 ha suggested by Map 6 (page 67).

Ultimately, the number and arrangement of patches required should be determined by a population viability analyses of focal species. This capacity is not yet available but has been identified as an area requiring further investigation (see page 72).

Although a substantial area (Map 7, page 68) is shown as suitable for woodland reconstruction, it may not be necessary to reconstruct all the patches. A more efficient process is to identify clusters of patches that could simply be joined to produce a 50 ha patch, rather than independently expanding each patch. Landholders will be able to identify circumstances where the desired outcomes could be achieved more efficiently than those specified on the map.

The results of the current analysis are the first step to developing a rigorous plan.

Patch Connectivity

General Issues

After determining the critical patch size and patch type for focal species, the next question is - "Are patches well enough connected to allow ready movement of birds between them?"

The placement of habitat patches plays an important part in determining whether animals are able to move around a landscape. As stated previously, the majority of reconstruction should occur adjacent to existing patches. However, simply adding to existing patches may not be sufficient in some cases. If patches are too far apart some species may be unable to gain access to critical resources such as food, nest sites or mates and they will be less able to recolonise isolated remnants if local populations become extinct. The ability to recolonise remnants following local extinction is critical if populations are to persist in the long term.

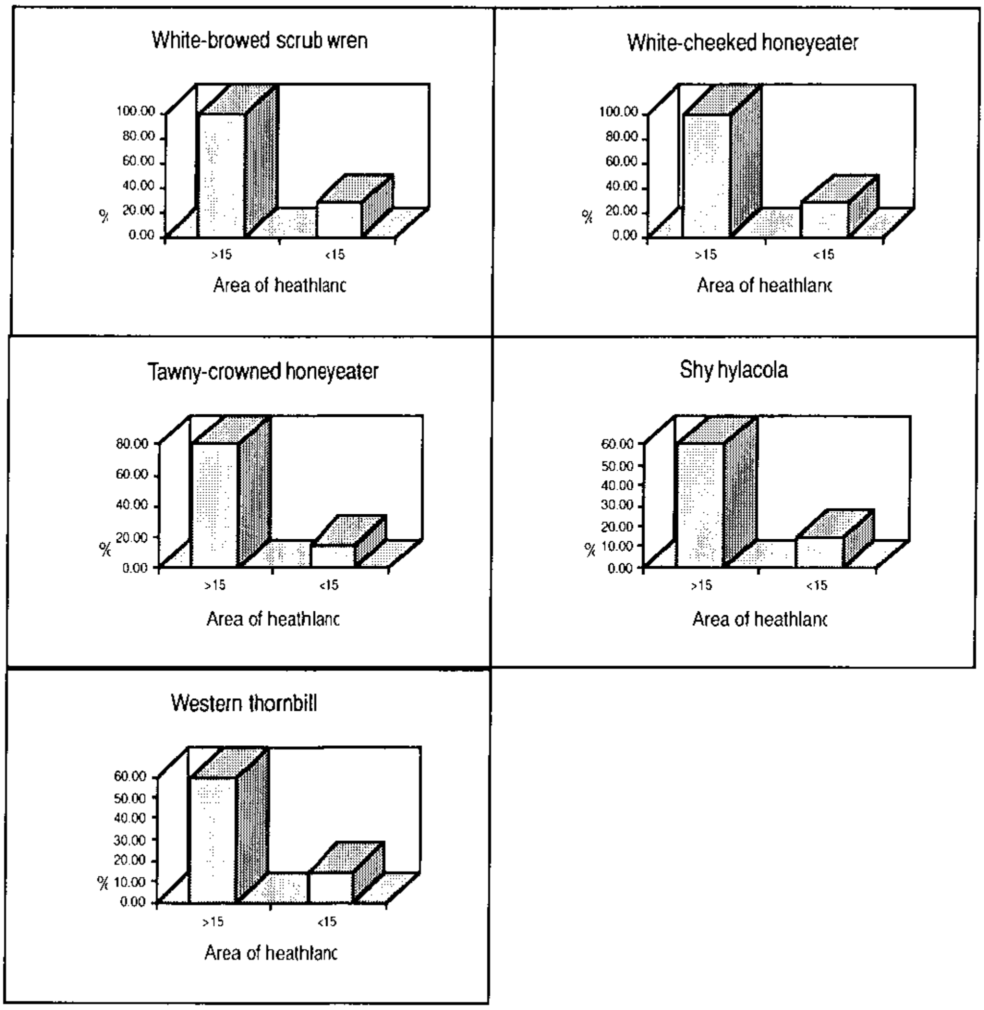
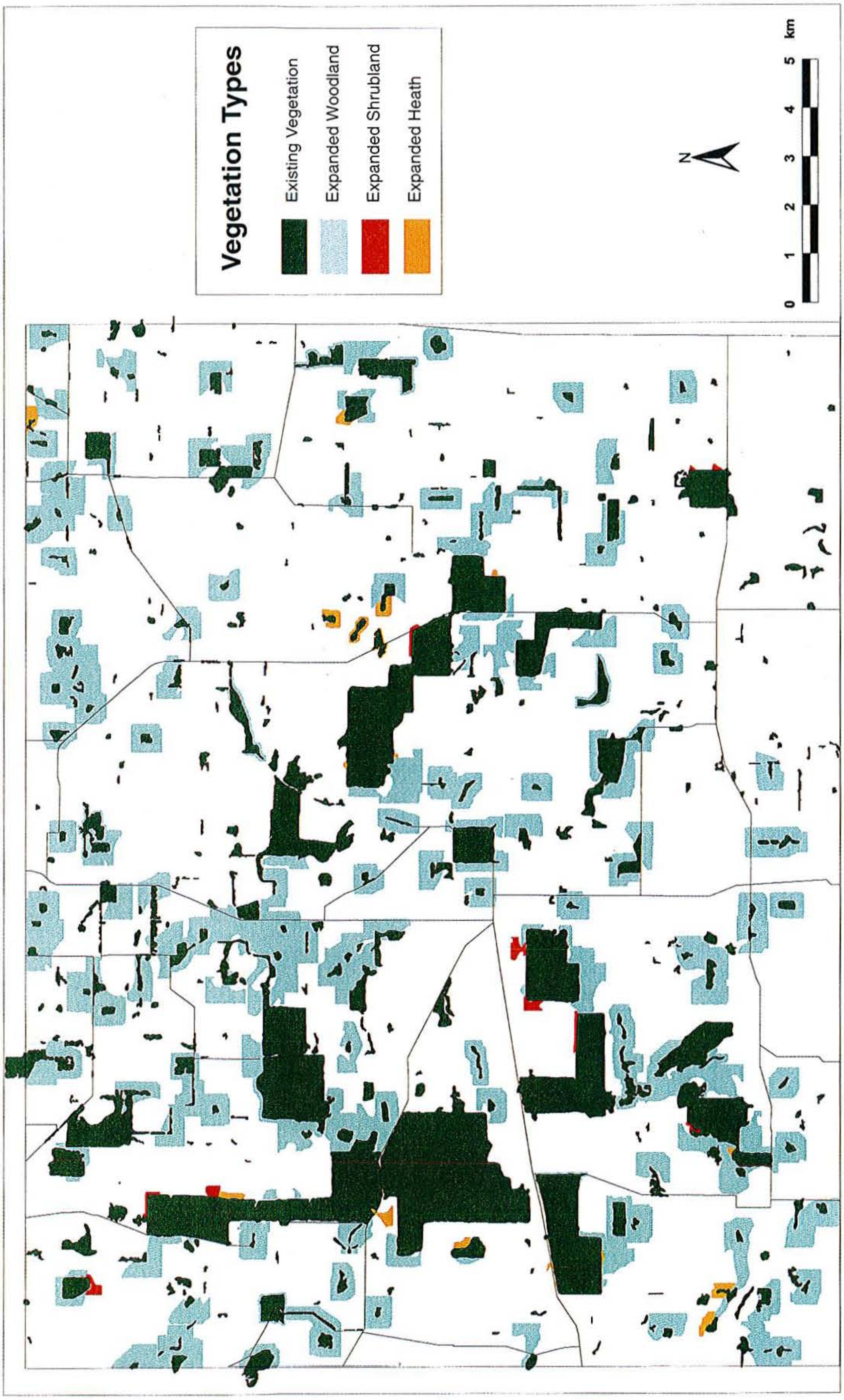
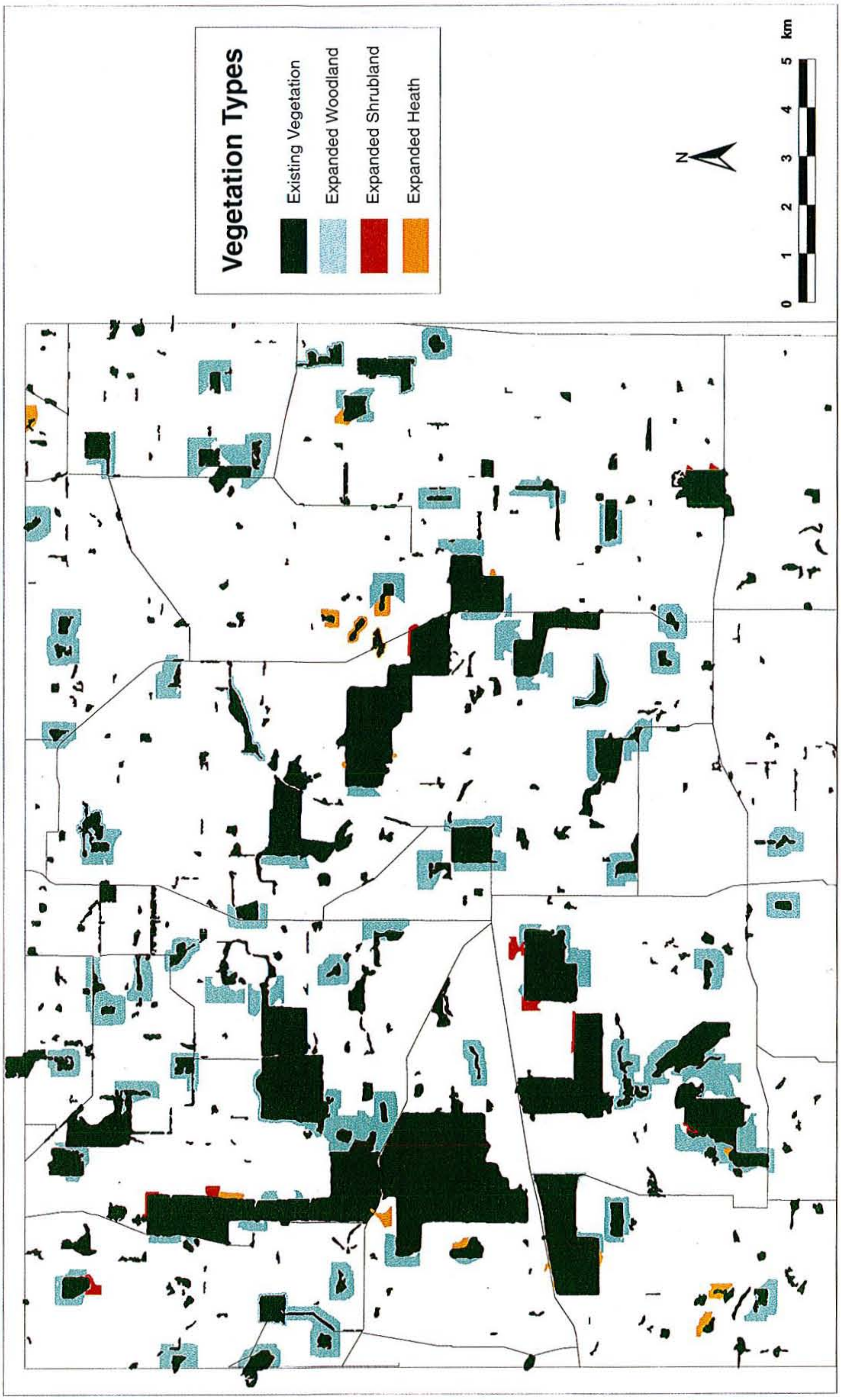


Figure 6: Patterns of patch occupancy of potentially vulnerable heathland birds. All of these species appear to be sensitive to the area of heathland in a remnant. Due to the small number of heathland patches in the area it was necessary to pool remnants into two size classes



Map 6: Areas suitable for habitat reconstruction in order to expand currently inadequate patches to a size that is sufficient to support the most area-limited species. This map is based on the enhancement of all existing patches that are currently greater than 2 ha and smaller than 50 ha



Map 7: Areas suitable for habitat reconstruction in order to expand currently inadequate patches to a size that is sufficient to support the most area-limited species. This map is based on the enhancement of all existing patches that are currently greater than 5 ha. This solution requires considerably less revegetation than is the case for Map 8

The likelihood of species moving between remnants will obviously vary between species. For highly mobile species, patches can be considerable distances apart and yet still have a high probability of being visited. Less mobile species, on the other hand, will require patches to be closer together. The requirements of the most dispersal-limited species are therefore used to determine the maximum acceptable distances between remnants. It is assumed that more mobile species will be able to move around a landscape that is designed to meet the needs of less mobile species.

Unfortunately, limited information is available regarding the movements of animals. In the absence of this information it is possible to use records of a species' presence or absence in different parts of the landscape to provide an indication of the capacity of that species to move around that landscape. If a species occurs in patches that are close together, but is consistently absent from patches of seemingly adequate habitat that are isolated, it is possible to infer that isolation is a factor that limits the distribution of that species. By gathering presence/absence records from a wide range of remnants it is possible to determine the distances beyond which suitable habitat patches remain unoccupied.

This information is available for some birds in the Dongolocking area. Although birds are not necessarily the most dispersal-limited group, they are the most cost-effective group to use, and some bird species are known, from studies conducted elsewhere, to be dispersal limited. These are characteristically birds that are sedentary, and dependent on native vegetation ("DNV") as identified by Lynch and Saunders (1991).

In this study isolation was measured as the distance from each surveyed patch to the five nearest suitable patches. This measure of isolation was used because a simple measure of the distance to the next nearest patch does not distinguish between a pair of habitat patches or a cluster of several patches.

Figure 7 (page70) shows the relationship between patch size and isolation for six species of woodland birds that were considered potentially dispersal limited. These figures suggest that, for the current landscape, isolation is not the major factor determining whether woodland birds are present in remnants. Focal and other species generally occur within the most isolated remnants with adequate habitat, and tend to be absent from small remnants regardless of their isolation.

Consequently, it does not appear that there is any need to create new, intermediate patches of woodland habitat for connectivity. The enhancement of existing patches is a much higher priority. However, the current connections between patches should be managed and protected.

Equivalent analyses for shrubland, heathland and mallee habitat were not possible owing to the small number of patches of these habitat types in the study area. In order to gain a better appreciation of the needs of species which use these patch types it will be necessary to conduct surveys over a larger area than that undertaken in the current study.

Corridor Designs

Not only do the current corridors need protecting through appropriate management, it is likely that improved connections may be necessary for some animals. In the case of birds, this is likely to be those that prefer denser shrublands. Therefore it is appropriate to briefly consider corridor design here.

When considering dispersal, it is necessary to bear in mind the amount of time that a dispersing individual needs to spend in a corridor. For highly mobile species, such as birds, this may amount to a matter of minutes, in which case the corridor need only provide shelter from predation and a pathway to a nearby patch of habitat. More sedentary species, such as small mammals and reptiles, may take days, weeks, months, or even years, to find their way from one end of a corridor to the other. Individuals of the most sedentary species may never be able to traverse the length of a corridor in their lifetime. For these species, it may be the descendants that emerge from the other end of the corridor several generations later. It is therefore important to distinguish between those species that use corridors primarily for movement, and those requiring corridors to provide significantly more of their habitat requirements.

Species requiring corridors mainly for movement: Birds, large mammals, larger reptiles such as varanids, and possibly some flying insects are likely to be the only species that are able to traverse the length of a corridor without stopping to use resources along the way. It is not likely that these types of species will have highly specialised requirements for corridor characteristics. The fact that woodland birds do not appear to be limited by isolation suggests that there is adequate connectivity for these species in the Dongolocking area. Species that are most likely to have special requirements will be those which normally occupy dense shrub and heath habitat and hence may be reluctant to move through narrow, sparsely vegetated woodland corridors. Such species are likely to require wider and denser corridors to encourage movement than will be the case for woodland species. It is therefore recommended that attempts to create or enhance corridors should primarily occur between remnants that contain shrubland and heathland habitat.

The primary areas where shrubland, heath and mallee occur are in the major reserves on the higher parts of the landscape. As a general recommendation, it is suggested that high quality linkages be established between these reserves, and that these linkages are sufficiently wide that they provide habitat as well as opportunities for movement. Preference should be given to the creation of shrubland, heathland and mallee habitat patches within these broad corridors.

Species requiring corridors that provide adequate habitat: Species that need to spend a greater amount of time in a corridor will be more sensitive

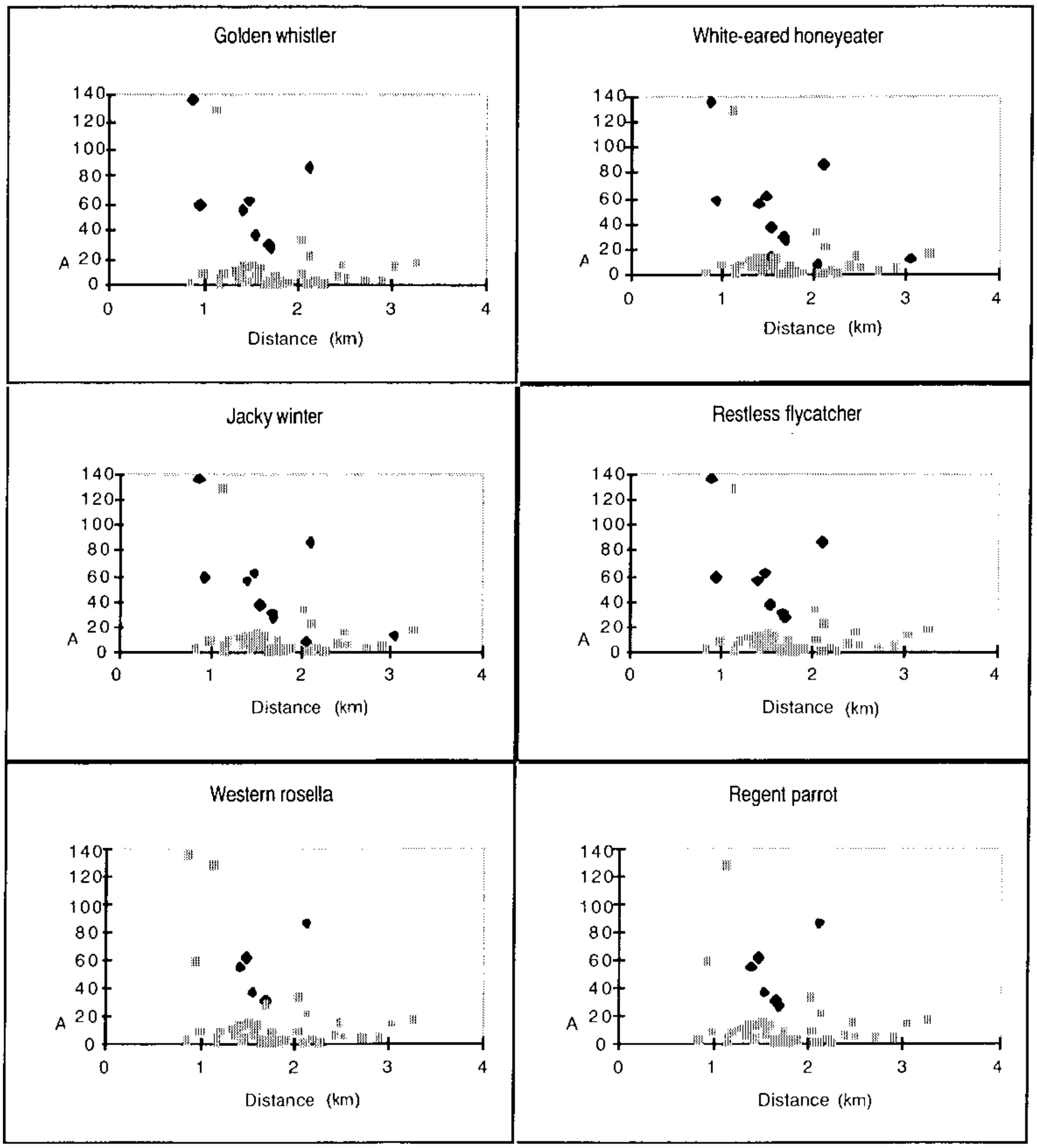


Figure 7: The relationship between habitat area and isolation for woodland birds
◆ indicates presence on a remnant; ▒ indicates absence. Isolation was measured as the mean distance to the nearest 5 woodland patches greater than 5 ha in size

to the habitat provided by that corridor. For these species, the corridor may have to provide adequate habitat, rather than simply a pathway from one location to another. Resources required to ensure that an individual can survive and successfully reproduce must be available in such corridors.

Small mammals, reptiles, invertebrates and plants were considered most likely to require corridors of adequate habitat. It was not possible, within the constraints of the current study, to identify particular species from these groups that fell into this category. Because of the presence of a number of large reserves in the study area, it was considered that many of these smaller species would have substantial populations within reserves. It must be recognised, however, that catastrophic events, such as high intensity wild fires, can potentially eliminate even large populations of small mammals and reptiles when they are confined to one or a few remnants. Studies elsewhere have demonstrated that some lizards, spiders and scorpions are threatened by fire (Smith 1995). If habitat patches are isolated, there will be little opportunity for recolonisation by these types of species. Consequently, these small mammals, reptiles and invertebrates require corridors consisting of adequate habitat if there is to be potential for recolonisation following local extinctions. For example, data from an ongoing study into the population dynamics of two geckos in the central wheatbelt (Sarre, Smith and Meyers 1995; Sarre 1995) could be used to design a corridor network in the study area.

In the absence of clear guidance about the minimum characteristics of corridors, a general recommendation for the study area is that, where used, they should exceed 40m in width between remnants. Between larger remnants, and also between patches containing vulnerable species and their nearest suitable habitat, corridors of 100 m are recommended. This issue and related issues should be addressed by future research.

Monitoring Strategies

To be effective, monitoring strategies must enable us to detect whether or not we are meeting our objectives. The type of monitoring strategy will therefore depend on what those objectives are. If our goal is to simply "make things better" without specifying the details of what we wish to achieve, then any increase in the distribution or abundance of any species could be taken as an indication of success. In reality, however, we are unlikely to consider an increase in the abundance of an already common species as a success. This suggests that we need to be more precise about our objectives. In this project we specified that our goal was to retain the species that are currently present. Therefore, ideally our monitoring strategy should detect changes in the distribution and abundance of any species.

However, it is not possible to monitor all species at all locations. Therefore, it is necessary to monitor a subset of the biota at a limited number of locations. As species increase in numbers we can expect them not only to become more abundant in the areas where they occur, but also to begin to occupy patches of habitat in which they were not previously found. An indication of the success of our management strategy would therefore be the colonisation of reconstructed habitat patches by area-limited and dispersal-limited species that were previously considered vulnerable. The first indication of success would be the appearance of these species in reconstructed habitat adjacent to patches where they currently occur. Subsequent success would be shown by colonisation of sites increasingly remote from source populations.

The ultimate measure of success would be the occupancy of sufficient new patches by habitat-limited species such that they could be considered viable in the new landscape. This is assuming that:

- the focal species selected do reflect the requirements of other species currently present at Dongolocking; and
- we know what constitutes a viable population (see page 72).

Such a strategy would require surveys to be conducted in a number of reconstructed patches at a range of distances from occupied patches. A range of currently occupied patches would also have to be surveyed in order to detect species declines and losses.

An obvious shortcoming of such a monitoring strategy is that the species that are the best indicators of success are those that are currently uncommon in the landscape and hence have small source populations from which to rebuild new populations. This means that there will be a long time lag between initial management actions and desired outcomes. An attraction of the approach used in this study is that species can be ranked according to their sensitivity to different threats and hence can provide some insight into the possible sequence with which species will respond to the amelioration of a threat. Presumably less sensitive species will respond more quickly than more sensitive species.

For habitat-limited birds it is possible to make rough predictions about the sequence with which species could be expected to occupy reconstructed habitat. For woodland, we may expect the most common farmland birds which like relatively open areas to arrive first. These will include twenty-eight parrots, magpies and willy wagtails. As the vegetation approaches 1-2 m in height and becomes denser, species such as singing honeyeaters, grey fantails, yellow-rumped thornbills and chestnut-rumped thornbills may be seen. As the taller vegetation exceeds 2m and understorey species spread out and commence flowering, rufous whistlers, western warblers, and more nectarivorous honeyeaters may occur. As trees exceed 5m and leaf litter and other debris accumulate, ground foraging species such as jacky winters will be encouraged back. Ultimately, as the full range of structural attributes develop within a tall woodland the full suite of woodland birds would be expected to occur. Similar recovery sequences could be postulated for bird species that use shrubland and heath.

It is important to acknowledge, however, that very few attempts at habitat reconstruction have been made and the suitability of reconstructed vegetation for the target species has not been tested. Consequently these predictions will, to a large extent, be speculative. On the other hand, the attraction of this type of assessment is that it will provide intermediate measures of success which will provide interim rewards for land managers. This is much preferred to a monitoring strategy that looks only for the final indicator of success which may be a long time coming and hence may result in disillusionment for landholders.

Because many of the design recommendations produced in this project are derived from the requirements of birds, it will be necessary to implement a monitoring strategy that tests the assumption that actions designed to benefit birds will also benefit other species. Pitfall trapping in a selected number of reconstructed sites should be undertaken to detect responses of reptiles, small mammals and invertebrates to the revegetation activities. Surveys for plant species other than those planted in the reconstruction phase should also be undertaken.

Long-term Viability

When assessing the capacity of a landscape to retain its plants and animals we need to consider two aspects of that landscape which can be termed "landscape adequacy" and "landscape viability". An adequate landscape is one which contains all of the resources required to meet the immediate needs of individuals of each species in the area to be managed. However, these resources may not be available in sufficient quantities to support populations that are large enough to be viable in the long term. A viable landscape, on the other hand, is one that not only meets immediate needs but can also support enough individuals for populations to persist in the longer term.

The approach presented in this report is able to address the issue of landscape adequacy, but not viability. If implemented, this procedure should ensure that the landscape will meet the needs of the species present over the time period specified in the project objectives. In the longer term, some species may still decline, not because of inadequacies of the study area, but because of the lack of action in adjoining areas. The solution may simply have not been applied to a large enough area. To ensure persistence in the longer term (hundreds of years) it may be necessary to consider conservation planning at a larger scale.

Two approaches can be taken to achieving landscape viability (Figure 8, page 74). The first of these is to increase the proportion of the landscape that is reconstructed in order to provide sufficient habitat to support viable populations of all species. This will come at significant expense to the landowners in the area. However, even if we reconstructed the whole of the study area, species that are naturally uncommon, such as wedge-tailed eagles or malleefowl, will still not have enough habitat to support viable populations. The alternative response involves extending the area over which the solution is applied. By taking this approach it may be possible to achieve population viability with reduced effort per unit area and hence reduce the cost to individual land-owners.

If we wish to specify the size of the response required to provide long-term population viability for all species we will have to gain an understanding of their population dynamics. This obviously cannot be done for all species. An important question that needs to be addressed is whether landscapes which will support viable populations of the more vulnerable species will also support viable populations of the other species. If this proves to be the case it will be possible to assess the viability of a landscape by determining whether it is able to support a carefully selected group of species.

Several workers have based minimum viable population (MVP) estimates on genetic and evolutionary factors. Frankel and Soulé (1981) calculate that an effective population of at least 50 individuals is required to maintain a rate of inbreeding of less than 1% and ensure short term preservation of fitness. Franklin (1980) argues that an effective population of at least 500 individuals is required to maintain long-term fitness, that is, evolutionary viability. If factors such as natural catastrophes, demographic and environmental uncertainty are added to the equation, then MVP estimates go up. Soulé (1987) estimated a MVP of an order of several thousands, whilst Thomas (1990) derived a MVP of 10 000 using empirical data from animal populations.

Whilst acknowledging that there are valid criticisms by several authors (for example, Boyce 1993, Shaffer 1981) concerning the applicability of these estimates of MVP to real-life management, it is possible to make a rough estimate of the ability of the study area to support viable populations. Estimates of population density can be obtained from the literature for some species, and when combined with measures of the area of suitable habitat, it is possible to make a crude estimate of the number of individuals that may be present in a given area. By comparing these estimates with the numbers suggested as being required for long term viability it will be possible to get a feel for the adequacy of the management strategy. However, it is important to remember that population size alone is not sufficient to assess viability. A large population that is declining rapidly may be no more secure than a small one declining at a slower rate. These coarse estimates will only be of use if we assume that the actions that we implement will ameliorate the processes that are threatening the biological diversity of the region.

On the basis of our survey data, it appears that patches of woodland need to be at least 50 ha to have a reasonable probability of supporting a pair of the most area demanding bird species. In the current landscape, there are only 7 remnants containing patches of this size suggesting a potential for supporting perhaps 14 individuals if there is only one pair in each patch. Under the revegetation recommendation to enhance all patches that are currently between 5 and 50 ha in size, the landscape would contain an additional 86 patches and hence could potentially support 186 individuals of the least common species. Given that these are estimates for the most demanding species, the benefits to other less sensitive species should be even greater. While this is a very coarse means of assessing viability, it does indicate that very strategic revegetation can potentially deliver significant improvements in population viability. By comparing these estimates with the figures for MVPs discussed earlier, it appears that the magnitude of the response in this study will be inadequate for the less common species over the long-term (100 years or more). This suggests that it will be necessary either to create a larger number of patches within the project area, or to increase the area over which the planning exercise is conducted, to ensure the long-term viability of the most sensitive focal species.

However, this is a simplistic approach that does not take into consideration the full range of threats. This would require a population viability analysis that takes into consideration disturbance regimes and other factors, in addition to those relating to population genetics and demographics. There is at least one published account of a population viability analysis relevant to the study area which models the effects of fire and fragmentation on populations of splendid fairy-wren near Perth (Brooker and Brooker 1994). A study into the population dynamics of the reticulated gecko in the central wheatbelt (Sarre, Smith and Meyers 1995, Sarre 1995) could also provide sufficient data for a population viability analysis to be conducted that is relevant to the study area.

Assumptions Made

Owing to the limited time available for carrying out the project, it was not possible to undertake comprehensive surveys or gain a complete understanding of the ecological requirements of the biota in the area to be managed.

A number of assumptions therefore had to be made based largely on work undertaken in the central wheatbelt. These assumptions include:

- *That landscapes designed and managed to meet the needs of vascular plants and terrestrial vertebrates will also meet the needs of non-vascular plants and invertebrates.* While this assumption may be legitimately challenged, we feel that the approach outlined here will provide design and management plans which can then be assessed by persons with expertise in other taxonomic groups. Such experts will be able to identify any shortcomings in the designs that we generate and suggest improvements that will enhance the design in a way that will accommodate their concerns.

- *That dominant vegetation associations can provide the "building blocks" for landscape reconstruction.* It is assumed that reconstruction of the dominant compositional and structural elements of each vegetation type adjacent to existing vegetation of the same type will result, over time, in the gradual formation of suitable microhabitat characteristics by natural processes. This raises issues for plant specialist species that need to be addressed in future work.
- *That birds are the species most likely to suffer from habitat loss and that minimum patch sizes can be based on the needs of the most area-limited bird species.* This is based on the broad assumption that the majority of mammals are primarily threatened by predation, or (in the case of honey possums and pygmy possums) by limits in the availability of critical resources; that plants are limited by processes such as degradation due to stock; and that the spatial requirements of invertebrates are a subset of those of vertebrates. For example, western brush wallabies have not been considered area limited in the current study as it is not possible to assess their area requirements while predation from foxes is occurring. It is possible that the removal of predators may result in this species subsequently needing to be considered area limited.

As discussed above, if research work in this project is extended, then it is intended to examine in more detail the usefulness of plants, reptiles and invertebrates as focal species, and their relationship to the bird species used in the work to date.

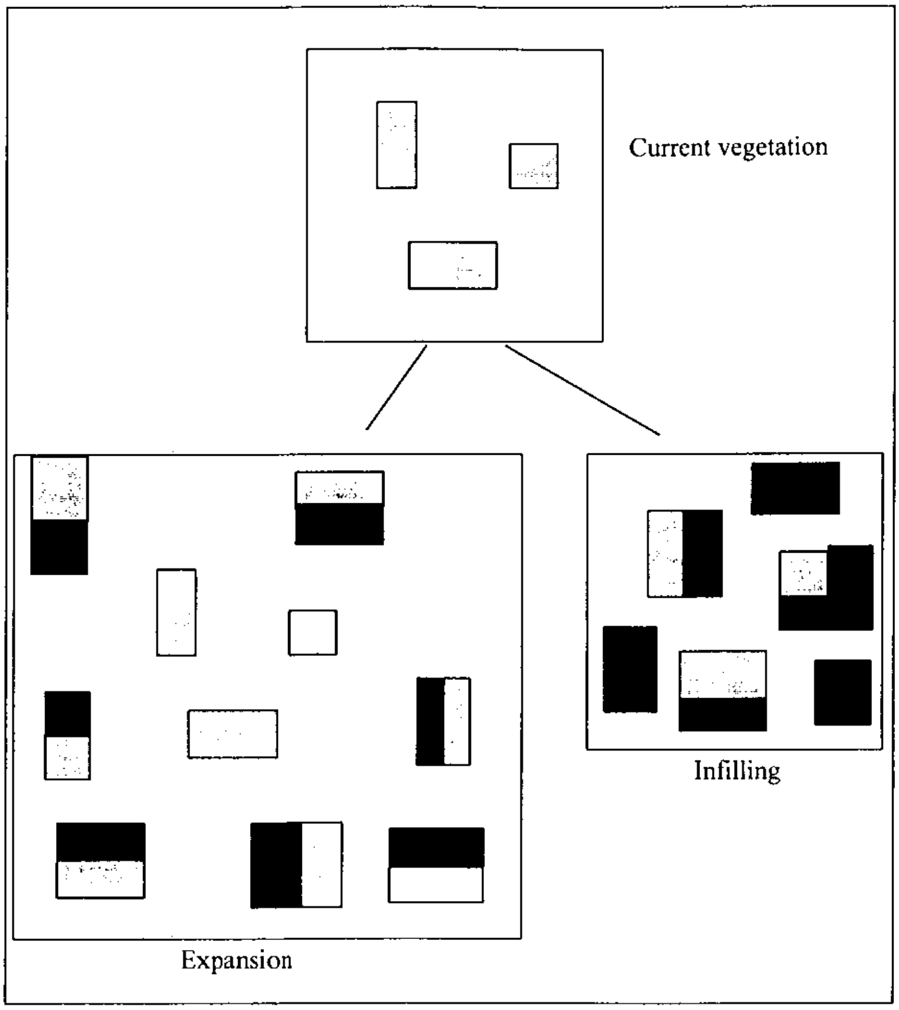


Figure 8: Alternative approaches to achieving viable landscapes using the same amount of habitat reconstruction. Dark patches represent reconstructed habitat. By applying the solution over a greater area the effort per unit area can be reduced

NATURE CONSERVATION AT THE LANDSCAPE SCALE — OTHER FACTORS

by Brett C. Beecham and Ken J. Wallace

Introduction

The complex interplay of threats that have determined the extent and composition of the current flora and fauna within the Dongolocking study area have been discussed in previous sections (see, for example, page 17). These threats include land clearing, predation by feral animals, disturbances (such as fire), environmental weeds and diseases, changes in hydrology, recreational demands and so on.

While most threatening processes must be managed at a range of scales, managing at the landscape scale provides the best avenue for:

- identifying priority targets for on-ground action;
- delivering cost-effective management by ensuring stakeholders work together on priority targets; and
- organising on-ground actions.

In the previous section, a process for dealing with the effects of land clearing by determining the adequacy of habitat available for species at a landscape level was developed.

A number of threats that should be considered at the landscape scale within the Dongolocking study area, additional to those dealt with in the previous section, are discussed below.

Disease and Environmental Weeds

Threat Posed

A global review of the consequences of biological invasions (MacDonald *et al.* 1989, cited in Carr *et al.* 1992) indicated that weeds may affect both ecosystem function and structure by:

- acceleration of soil erosion;
- alteration of biogeochemical cycling;
- alteration of hydrological cycles;
- alteration of other geomorphic processes;
- alteration of fire regimes;
- prevention of recruitment of indigenous species;
- acceleration of extinction rates; and
- genetic changes.

Specific examples of the effects of plant invasion on ecosystem function are also provided by Hobbs and Humphries (1995).

Landscape Management Strategy

Weeds are a management issue at both the individual remnant (or farm/property) level and at the landscape scale. A strategic approach to environmental weed management is required at the landscape level because:

- The causes of plant invasion are often found at the ecosystem/landscape level, and these need to be addressed at this level before effective control can be implemented (Hobbs and Humphries 1995).
- Efforts to prevent the introduction of new disease and weed species are more likely to be effective (although relying on the co-operation of individuals) than at the remnant or property level. This is the single most important measure, and also the most difficult to achieve. New weeds usually manifest from the deliberate introduction of a species for agricultural purposes, from the introduction of ornamental species, or from propagules inadvertently brought in with machinery, seed supplies or hay/straw.
- All stakeholders can be consulted, a list of priority objectives agreed to, and management efforts can be co-ordinated (rather than several *ad hoc* control efforts with no co-ordination).
- Target species and control strategies can be readily ranked to ensure scarce resources are utilised to achieve the maximum effort in meeting conservation objectives.
- Weeds that are likely to effect ecosystem processes (which generally operate at broader scales) can be managed more effectively.

Diseases such as *Phytophthora* spp, which have not been recorded for the Dongolocking study area, are best managed by preventing their introduction through quarantine measures. At present CALM is responsible for quarantine and management guidelines for preventing the introduction of the disease or containing any outbreak within nature conservation reserves. Similar guidelines for other remnants would need to be developed and implemented.

To rank weed management from a nature conservation perspective, a process is required to systematically analyse the relative threat posed. The key issues and the information required to understand each are listed below:

Threat
- the impact of the weed on species diversity, including threshold points for decline, and other values (for example, Adair and Groves 1998); and
- the impact on ecosystem level functions and processes (for example, Adair and Groves 1998).

Invasiveness
- ecology of the weed species;
- the processes leading to invasion;
- the range of habitats susceptible to invasion (including any management practices or disturbance regime affecting susceptibility); and
- the rate of spread within and between susceptible habitats.

Control
- the prospects for the containment or control of the weed, including the detection and identification of new species or new invasion foci, technical means of controlling, cost of control, etc. (for example, Csurhes and Edwards 1998).

Occurrence
- identifying the weeds present or likely to invade (based upon bioclimatic modelling, probability of introduction) (for example, Csurhes and Edwards 1998).

By assigning relative values to each of these it is possible to rank weed management for nature conservation, or a range of other values (production, recreation etc). See Mulvaney (1997) for a discussion and example of the risk assessment process.

Documents currently in preparation, such as the National Weeds Strategy and the Western Australian State Environmental Weed Strategy, will provide a framework for ranking and managing threats posed by weeds to nature conservation values.

Priority Species

There has been no systematic survey of environmental weeds within the study area. However, CALM officers have undertaken some control work on bridal creeper and perennial veldt grass. Examples of environmental weeds that significantly threaten nature conservation at Dongolocking are:

1. Those invading vegetation communities on the more fertile soils. These communities include salmon gum, York gum and morrel woodlands. These woodlands are often reduced to small remnants, have been highly disturbed, and are situated on fertile soils conducive to weed invasion. Such woodlands are also highly valuable for nature conservation as they support a range of dependent flora and fauna and are poorly represented in conservation reserves within the agricultural zone.

   Exotic annual grasses pose a major threat to these woodland communities by outcompeting the native understorey species, and the following are a high priority for control:

Wild Oats	*Avena* spp
Bromes	*Bromus* spp
Blowfly grass	*Briza* spp
Rye Grass	*Lolium* spp
Fescues	*Vulpia* spp

   Whilst individually these species are not always a significant threat to nature conservation values, considered collectively they are particularly damaging. This highlights the importance of dealing with weeds collectively when considering their impacts on natural species, communities or ecosystem processes.

2. Several species that should be controlled wherever they occur, as they are highly invasive and have a major impact on nature conservation values. These are:

Veldt Grass	*Ehrharta calycina*
Bridal Creeper	*Asparagus asparagoides*

Exotic Predators

Threat Posed

The red fox, and to a lesser extent the feral cat, are the most significant exotic predators in much of Australia including the Dongolocking study area. They are known to predate a wide range of native mammals, birds, reptiles, amphibians and invertebrates, and are implicated in the extinction of several marsupials within Australia. At least thirteen native mammals have become locally extinct within the study area, and predation by the fox and feral cat is likely to have been a significant factor. One of the other key groups of fauna to be significantly threatened by exotic predators are the ground-nesting birds such as malleefowl and bush stone-curlew.

Landscape Management Strategy

Control programs aimed at a single species, such as foxes, may lead to an increase in numbers of rabbits and feral cats. The population level predator-prey interactions between foxes, cats, rabbits and native fauna is complicated. A management program that incorporates control of all three major vertebrate pests is likely to achieve better results than dealing with each species individually. Research suggests that in order to control predators such as foxes and cats, rabbits need to be controlled first (Newsome 1990).

This emphasises that the planning of predator control programs is best designed and implemented, where resources permit, at the landscape scale so as to manage the population interactions of all the species involved.

Therefore, where practicable, it is important to conduct integrated pest animal control programs to protect wildlife at a landscape level.

Hydrological Management

The need to address rising water tables, surface waterlogging and other hydrological threats at landscape scales is well recognised. This important issue will be addressed in phase II of the project.

Fire Management

To address the threat of a fire sufficiently large to cause animal or plant extinctions within the study area requires:

- Planning for recolonisation in the event of a catastrophic fire. This is an issue that is addressed in comments on corridors in the previous section. The concept requires further development, but revegetation will be planned to meet the needs of recolonisation; and

- Planning and implementing fire protection measures. This involves a large number of stakeholders, and would be best addressed through a shire fire management plan. Whether such a plan is undertaken will depend on the wishes of all stakeholders.

Recreation, Illegal Activities, Mining, etc.

These, and a range of other issues may be usefully addressed at the landscape scale as well as at the scale of individual areas or sites. However, they are not priority threats under this Plan, and will not be further developed unless it proves necessary to do so.

NATURE CONSERVATION AT THE REMNANT SCALE

by Robert J. Lambeck and Ken J. Wallace

As described in "Nature Conservation at the Landscape Scale - a Framework", direct management of threats is vital to achieve nature conservation goals. Managers may operate at one or more of the following scales:

- individuals;
- populations;
- specific, identifiable areas of bushland;
- landscapes; and
- bioregions and larger scales.

To successfully counter threats to our native biota management must occur at each of these levels. In this section the management of specific, identifiable areas of bushland is discussed. This scale of management is convenient for many land managers.

Protecting remnant vegetation is essential if we are to retain the unique plants and animals that occur throughout the agricultural region of Western Australia. Native vegetation not only provides essential habitat for native species but also contributes to important ecosystem services - such as ground-water control, pollination and nutrient cycling. These services are essential for maintaining both the diversity of plants and animals and sustainable land use systems. The extensive clearing of habitat for agriculture means that few, if any, remnants are large enough to support on their own all the species they presently contain. Therefore while this section focuses on management of individual remnants, it must be remembered that persistence of many species in agricultural landscapes relies on the ability of animals to move between remnants in search of mates, food and other resources. Many plants also depend on the movement of animals to maintain pollination and seed dispersal. When managing our remnant vegetation it is therefore important to consider not only the individual remnants but also the pattern of these remnants throughout the region. These landscape issues are dealt with in the preceding two sections "Nature Conservation at the Landscape Scale - Adequacy of Habitat" and "Nature Conservation at the Landscape Scale - Other Factors".

Management of individual remnants is largely a matter of managing the threats that impact on each remnant. These threats are discussed in "Threats to Current Land Use". In the case of individual remnants at Dongolocking, the most important issues, aside from landscape scale issues, are management of:

- stock grazing and trampling;
- problem plants (such as veldt grass);
- problem animals (such as the fox);
- regeneration and rehabilitation;
- pesticides and fertilisers on adjoining lands;
- fire; and
- rising water tables.

Initially it was planned to deal with these and other issues with particular reference to the Dongolocking area. After drafting several sections, it became apparent that we were largely re-covering ground that is already dealt with in *Managing Your Bushland* (Hussey and Wallace 1993). It was therefore decided that it would be more useful to produce a series of A3 (or similar) information sheets based on the Hussey and Wallace publication and new information. For these to have maximum value as extension tools, they would be converted into a form that incorporates actual examples along with diagrams and photographs. This approach is developed further and proposed for completion under phase II of the project (see "Works Required to Complete Plan").

Therefore management techniques for individual remnants will be dealt with in phase II. However, apart from actual management practice, in the face of limited resources it may not be possible to find the human and financial resources to manage all remnants with the same intensity. It is therefore necessary to set priorities which identify the most important remnants for intensive or immediate management. This issue is dealt with below.

The removal of native vegetation has caused the loss of numerous plant and animal species and has contributed to severe land degradation including erosion and rising saline water tables. In the face of these problems, it would appear that all remaining remnant vegetation is important and should be protected. However, some remnants will make a greater contribution than others to: protecting flora and fauna, and contributing to land and water conservation. Depending on availability of resources, it may be necessary to rank remnants in terms of their importance so that funds are allocated to the highest priorities for management.

The remainder of this section addresses factors that need to be considered when selecting priority remnants. These factors may be separated into:

- intrinsic values at a point in time; and
- viability values.

It is emphasised that any ranking system is highly subjective, an issue covered in the work referred to below by Safstrom (1995).

Intrinsic Conservation Values

Intrinsic values are the conservation values that a remnant has today without any consideration of how these may be affected by viability factors. It is important to make this separation so that the actual values of a remnant today may be judged separately from how viable the remnant is in the longer term. Viability will be affected by management and should not be confused with the intrinsic values of a remnant at a point in time. A final priority rating may, of course, include both factors.

Safstrom (1995) has provided a procedure for evaluating the intrinsic conservation values of individual remnants. The main points that he identified are summarised in Table 38 (page 81), but the reader is referred to the original document for a more detailed description of the approach. The criteria that he considers most useful include:

- the presence of threatened flora or flora of special interest;
- the presence of threatened communities;
- the number of plant associations;
- the presence of threatened fauna;
- the size of the remnant;
- the area of vegetation in "good" condition;
- the shape of the remnant - remnants with less edge are more resilient to external impacts than are long thin remnants; and
- proximity to other reserves or large remnants.

While in ideal circumstances intrinsic values would include more refined measures of biodiversity than those proposed by Safstrom, these are very expensive to obtain and rarely available. It is doubtful that the addition of other factors would significantly alter the evaluation of a remnant. Of more importance is how variables are weighted when they are used to generate a list of priorities. This issue is covered by Safstrom, and the method he proposes allows priorities to be assigned with various weightings. This properly emphasises that any priority-setting system will have a significant subjective component.

Viability Values

Safstrom also recognised that the value of a remnant depends on its longer term viability. Viability is viewed as the probability of a reserve persisting into the future without serious degradation. Serious degradation is defined as loss of vegetation strata such that the normal ecosystem functions of regeneration and recycling are unlikely to continue operating after 50 years. Factors that influence viability are listed in Table 39 (page 82). Most important among these are:

- shape and size - reserves with widths of less than 100 m were considered to have low viability;
- position in landscape - remnants low in the landscape will be less viable if salinity isn't managed;
- adjacent land uses - particularly if they involve drainage of saline water;
- intactness - assessed by the presence of weeds; and
- connectivity - remnants close to other remnants that are linked by native vegetation will have greater viability for many species. While not listed as a suitable criterion in Safstrom's report, there is sufficient data at Dongolocking for this criterion to be used effectively.

On the basis of this type of analysis it is possible to identify a set of remnants that should have highest priority for management. High priority remnants in the Dongolocking area are shown on Map 8 (page 83). The fact that some remnants are considered a lower priority does not mean that they are not important. It is essential to recognise that lower ranking remnants may play a critical role in maintaining the numerous species that require a number of remnants to support viable populations.

Table 38: Summary of intrinsic nature conservation values and whether or not they are suitable for use in reserve evaluation (from Safstrom 1995)

Criterion	Suitable	Reason	How used
Rare flora and flora of special interest	yes	Important to protect rare and special flora. No information may not indicate absence of threatened or special species.	Reserves with rare or flora of special interest given higher priority. [Could also use focal species.]
Threatened communities	yes	Important to give threatened communities high priority for protection.	Reserves containing Class I communities are a higher priority for protection than reserves with Class 2 or Class 3 communities.
Species richness	no	Comparative measures not possible, species poor sites may be of higher conservation value than species rich sites.	Not used.
Rare fauna	yes	Important to provide protection for rare fauna. No information may not indicate absence of rare fauna.	Difficult to use in practice due to survey limitations. Reserves with rare fauna can be given higher priority. [Also, could use focal species.]
Reserve area	yes	General agreement that nature conservation values increase with reserve size.	Used as a continuous variable rather than defining area classes, but arbitrary area cut off can be used for specific purposes (eg. NPNCA reserves should be greater than 80 hectares?)
Intact area.	yes	Little data available on relationship between reserve degradation and nautre conservation values. Intact area considered to be a potentially useful indicator.	Areas of each weed cover class measured. Intact areas defined as areas with less than 20% weed cover. Used as a continuous variable rather than defining area classes, but arbitrary area cut off can be used for specific purposes.
Plant diversity (number of plant associations) and plant diversity as a measure of fauna diversity	yes and no	Increasing diversity important for maximising flora and structural diversity but not necessarily related to greater fauna conservation value. Values are fauna species and scale specific.	Used as a measure of increasing biotic diversity but with caution in relation to fauna.
Remnant shape and edge effects	yes and no	Edge effects are species and vegetation specific. Lack of information regarding core area requirements of species.	Used for small narrow reserves with significant areas less than 100 metres in width. Such reserves are considered to have low viability.
Time since clearing or isolation	no	Time since clearing can be important re local extinctions but information unavailable.	Not used.
Intactness - reserve quality	yes	Levels of weed invasion gives non subjective repeatable picture of reserve degradation provided other causes of degradation are separately recorded.	Weed cover mapped into 4 classes: 0-20%, 20-50%, 50-80%, 80%+ and area of each class measured. With map of features, roads, gravel pits provides a visual picture of reserve degradation. Reserves with large highly degraded areas considered non viable.
Relationship to NPNCA reserves	yes	Reserves may contain habitat not already conserved or significantly add to habitat already conserved or be considerable distance from a reserve.	Reserves have a higher priority if they contain habitat not already conserved or significantly add to habitat already conserved or are further than 15 km from a NPNCA reserve.

Table 39: Summary of non human, biological and physical influences which affect viability (from Safstrom 1995)

Influence	Suitable	Reason	How used
Shape and size	yes	Small narrow reserves are subject to external influences and degradation over much of their area.	Small narrow reserves with significant areas less than 100 metres wide are considered to have low viability.
Vegetation associations	no	The resilience of different plant associations to change is largely unknown.	Not used.
Time since clearing	no	Lack of information on isolation of each reserve. Could be a valuable criteria re extinctions if information available.	Not used.
Position in landscape - rising water tables	yes	Rising water tables and salinity can alter, degrade and kill existing vegetation.	Where there is evidence of rising water tables affecting or likely to affect a reserve then that part of the reserve affected is considered to have low viability
Adjacent land uses	yes	In the wheatbelt adjacent land uses appear to have a low to moderate effect on reserves save where saline water is drained into reserves when the impact is high.	The parts of reserves affected by drainage of saline water from adjacent land are considered to have low viability.
Exotics - intactness	yes	Exotic plants and animals can cause serious damage. Weed invasion can be measured (refer intactness).	Reserves with no or very small areas of intact vegetation are considered to have low viability. Small occurrences of highly invasive weeds have potential to influence viability.
Isolation - configuration and connectivity	no	Value of measures of configuration and connectivity is species dependent. Consistent data could not be collected.	Measures of configuration and connectivity in this study should be used only as a guide due to inconsistent data. Generally it is considered that proximity of quality adjacent remnant vegetation and greater connectivity improve viability.

Map 8: Remnants having high priority for management on the basis of their size, vegetation diversity or the presence of priority species

by Ken J. Wallace

Four major outputs are required to finish the Plan. These are:

1. Guidelines for remnant management in a format that is user-friendly from a landholder viewpoint;

2. Detailed revegetation plans for property owners that integrate multiple land use objectives at farm and landscape scales. During this work, revegetation designs that have broad applicability in low rainfall, agricultural areas will also be developed;

3. An implementation strategy and works plan, including incentives and cost sharing arrangements; and

4. A description of the implications from the work at Dongolocking, including development of a research programme to meet knowledge gaps identified during the project.

Each of these elements will be completed in phase II of the project. The costs of completing these items, together with progress to date, are discussed below.

User-friendly Guidelines for Remnant Management

Part of this project was to produce guidelines on remnant management for Dongolocking landholders. During preparation of early drafts, it became clear that excess time was being spent on paraphrasing information published in *Managing Your Bushland* by Hussey and Wallace (1993). Rather than replicate past work, it was decided it would be more useful to produce a series of A3 (or similar) information sheets based on the Hussey and Wallace publication and new information. For these to have maximum value as extension tools, they should be converted into a form that incorporates actual examples along with diagrams and photographs.

The values of such a product are that it would provide:

- A more user-friendly format than those currently available. While *Managing Your Bushland* (Hussey and Wallace 1993) is a very useful product, it was always intended to break the subject matter into the smaller "bites" of information preferred by some land managers and their advisers. The Dongolocking project provides an excellent means of achieving at least part of this objective.
- Information that is widely applicable in the agricultural region. This would make a direct contribution to "Land for Wildlife" type bushcare programs being developed within the State.
- Core extension material that would contribute to the Dongolocking area becoming a very useful demonstration, education and training site.

Considerable effort has been expended on drafting material in preparation for this proposed project. However, this material has not been developed to a level suitable for distribution.

It is estimated that to take the current information to publication will cost:

Photography and re-writing of text	$15 000
Design and drawings	$10 000
Printing	$ 5 000
Total	**$30 000**

Development of Revegetation Plan

This is the most important part of the project. It is the vehicle by which landscape objectives will be combined with other land use objectives, including achievement of sustainable, profitable agriculture, in revegetation plans tailored to the needs of individual landholders. These farm plans will take into consideration sustainable land use and conservation of biodiversity at both landscape and farm scales.

Components of this part of the project, and their estimated cost (not including State agency contributions which will largely involve project management and supervision), are described in Table 40 (page 87).

The main output will be farm revegetation plans cast in a broad land use context. However, to ensure external funds used in revegetation are applied strategically, a consultant will also prepare a report ranking works along with an explanation. It is proposed that this report, along with other planning documentation, will provide the basis for applying Bushcare funds to achieve on-ground outcomes.

Documentation under this part of the project will also include a set of revegetation designs. Participants at the Springhill Workshop held in 1996 (funded by LWRRDC) identified planting configuration and floristic composition for a range of land use objectives amongst the highest research priorities. Designs developed during this part of the Dongolocking project will contribute to meeting this need, and will have wide application throughout similar rainfall and topographic zones. There will be particular emphasis on developing designs that meet nature conservation goals while utilising potentially commercial local and regional species. Consequently, harvesting and silvicultural comments will be necessary with some designs to ensure that conservation and production may be integrated.

Development of an Implementation Strategy Including Monitoring, Incentives and Cost-sharing Arrangements

It is expected that the implementation strategy and works plan will consist of a list of priority actions generated during the development of revegetation plans combined with critical management tasks for remnant vegetation. Apart from information on monitoring, the strategy will also describe cost-sharing and related arrangements. These documents are expected to be short as detailed justification will be contained in other parts of the Plan. Discussion and concept development in this component will therefore focus on incentives and cost-sharing arrangements.

Work has begun already (see below) in this project on how incentives and cost-sharing may work in the case of the Dongolocking Study Area. The aim is to develop a methodology that may be applied throughout the agricultural region of Western Australia.

An important issue to be dealt with in this section is that of landholder rights to harvest from revegetation planted as "commercially prospective". This is an issue of concern that has been raised by some Dongolocking landholders. The framework for developing incentives for revegetation and conservation of remnant vegetation is based on five broad ways of accomplishing changed behaviour. These are as follows (based closely on Wallace 1994):

1. *Facilitate Change in Social and Cultural Values*
   If people deeply believe, for whatever reason, that revegetation with perennials and conservation of remnant bushland is in their best interests, then appropriate action will follow constrained only by resources. Some of the relevant issues are explored in Burbidge and Wallace (1995). There are many important aspects to this including:
   - education at all levels;
   - helping key players in the rural community to bring about positive change in rural values. This point in particular acknowledges the important role of the farming subculture in land management decisions (Vanclay 1992); and
   - success with items (2) to (5) below, all of which may influence socio-cultural change.

2. *Make It Economic*
   As net returns to landholders from revegetation with perennials and conservation of remnant vegetation increase, adoption of these management practices will also increase. Means for achieving this include:
   - researching and extending productive uses of perennial revegetation and remnants;
   - increasing government assistance to actions favoured by government;
   - attracting more private enterprise assistance to remnant managers and revegetation works; and
   - providing special economic incentives, for example, special tax concessions and rate rebates.

3. *Make It Compulsory*
   While it will not be part of the Dongolocking project, the role of legislation and regulation in bringing about sustainable land use outcomes is acknowledged.

4. *Make It Easier - Improving Understanding and Knowledge*
   Lack of information, conflicting information, complexity of the issues to be tackled and the

Table 40: Components of preparing a detailed revegetation plan (costs shown do not include State agency contribution)

Task	Action by	Output	Cost (External Funds)
1. Landholders, consultant and agency personnel to develop revegetation plans that meet specific landholder needs. During this component, landscape issues will also be considered. This work will be done simultaneously with actions (2) and (3).	Consultant Bicknell Wallace	See item (3)	See item (3)
2. Landholders, consultant and agency personnel to develop revegetation action plans for nature conservation (based on Lambeck's work). This information should include species composition, design elements, and estimated costs.	Consultant Lambeck Bicknell Wallace	See item (3)	See item (3)
3. Landholders, consultant and agency personnel to develop revegetation actions that protect high priority remnant vegetation. Wherever practicable this will aim at combining profitable agriculture and nature conservation. Catchment water use "needs" will also be taken into consideration. Funding ($20 000) has been allocated for this latter purpose. The development of commercially prospective local species will be an important component of this step.	Consultant Beecham Bicknell Wallace	Individual farm plans that aim to meet the needs of: • landholders; • biodiversity conservation; and • broader, regional needs, particularly with regards to water use. Parts of the individual farm plans will, when combined, form a landscape plan for the study area.	65 000 (cost of 1-3 inclusive)
4. A set of recommendations concerning the allocation of priorities for funding to specific revegetation proposals developed under the farm plans.	Consultant Bicknell Wallace	A short report detailing priorities for action, particularly with reference to external funding.	2 000
5. Compile a document of revegetation designs including: configuration, species composition to meet integrated land use goals.	Consultant Beecham Bicknell Wallace	A technical document incorporating, with explanation, designs and species to meet integrated land uses.	8 000

risk and uncertainty of new innovations are all barriers to adoption (see Vanclay 1992) of new technologies. Improving the understanding and knowledge of all stakeholders involved in revegetation and remnant management is important to encourage effective action. Some of the many ways this could be achieved include:

- providing better information;
- raising understanding and awareness of revegetation and remnant values, particularly in relation to salinity control and on-farm profitability;
- encouraging meetings, particularly in the field, of all stakeholders to facilitate exchange of ideas and development of innovative solutions;
- undertaking technical and other research to improve knowledge; and
- developing better tools for land management decisions, particularly with regard to integrating different land values.

5. *Provide Non-economic Incentives*
There are non-economic incentives which might be used to reward people for appropriate revegetation and conservation of remnants. Most obvious are the awarding of prizes and similar forms of special recognition. Another approach is to make covenants, memorials and related means of protecting bush more available and relevant to individual needs.

These five mechanisms are not mutually exclusive - they overlap and interact. To achieve revegetation and remnant conservation that meets the broad range of land use objectives, it will be necessary to combine action in each of the five areas listed. Whatever mix of incentives and cost-sharing is used, it is essential to monitor actual implementation closely. If adoption is slow, then mechanisms must be available to re-visit and revise the incentives/cost-sharing mix in consultation with stakeholders.

While all five mechanisms for change will be used to some degree, incentives and cost sharing during the Dongolocking project will primarily be based around items (2) and (4).

The project will directly contribute to improving the fund of knowledge and understanding of revegetation and remnant conservation. Increased knowledge and understanding should, as a result of the project, be apparent in all key stakeholders including farmers, agency land managers, researchers and others who have participated in the project. In a very real sense, knowledge is being shared among the stakeholders, and it is essential that this process is enhanced. The final report for phase II will deal with this issue in more detail.

As part of this project, a number of methods for cost-sharing, the major form of economic incentive to be used, have been examined. These may be divided into two types:

- cost sharing for conservation of existing remnants; and
- cost sharing for perennial revegetation to integrate and achieve a range of land use objectives.

These are described below. While both subjects will be dealt with in phase II of the project, the aim of the outline here is to stimulate comment upon which to further develop cost-sharing methods.

Cost Sharing for Conservation of Existing Remnants

Over the past decade the protection and management of remnants of native vegetation on private property has been a major focus for nature conservation in agricultural areas. Despite this attention, Crown land remnants (at least in Western Australia) are the major reservoir for biodiversity, and their protection and management is an important issue. Over the past decade the focus on private property remnants has often obscured the high value of Crown remnants. In Western Australia, the value of Crown remnants has been recognised through the Salinity Action Plan under which new funds have been allocated to protection of Crown reserves in agricultural areas. Crown reserves will not be considered further here under cost sharing arrangements, however, given their importance, additional material may be added during phase II.

The remaining remnants in the study area are held under freehold title. The cost sharing options available for their management are covered in publications such as those by Clairs and Young (1995) and Binning and Young (1997). However, other approaches may be considered during development of cost sharing options. For example, Vogel (1992) has suggested that landholders be given genetic property rights as a means of encouraging private funding of conservation management.

All these alternatives will be canvassed during Phase II of the project.

Cost Sharing for Perennial Revegetation

Reports by the Murray-Darling Basin Commission (1996) and Marsden (1996) provide a good summary of cost-sharing methods. While approaches they promote have been considered in relation to cost-sharing for revegetation at Dongolocking, they are not favoured because:

1. Developing a cost-sharing framework would probably cost $50 000 and take about 12 months (based on Murray-Darling Commission's estimate for a much larger area, but farm forestry only, and therefore less complex revegetation). This is prohibitive in the context of this project, both in terms of funding and time;

2. A simpler, more widely applicable approach based on land use goals is likely to be more easily understood by all stakeholders, and has the advantage of focusing on goals. (However, the connection of goals to cost-sharing could be counter-productive if it discourages land managers from implementing nature conservation works.); and

3. They do not satisfactorily account for those actions that are negative to land use goals. For example, they do not account for the use of weedy species in revegetation.

However, the approach proposed here is in its early stages of development, and it may prove unworkable. Two alternative approaches that will be considered during phase II are that described by Marsden (1996) for assessing joint outcomes, and a system that involves salt and water disposal "credits" issued to landholders.

It is proposed that cost-sharing arrangements for Dongolocking (and similar areas) are based on the relative contribution of actions towards achieving primary land use goals. At Dongolocking, the two primary land use goals are profitable agriculture and nature conservation. While there are other land uses, such as recreation, these occur at such a low level that they are not significant, or their needs are broadly covered by the primary land uses.

Principles used as the basis for cost-sharing are:

1. Individual land managers should fund actions that mainly contribute to profitable agriculture, and not other land use goals;

2. The community should fund actions that mainly contribute to nature conservation, and not other land use goals;

3. Where benefits accrue to both goals, costs should be proportionally shared by the beneficiaries; and

4. Each revegetation action may be rated according to its level of benefit, or detriment, to the two land use goals.

A scheme for rating actions, as described in (4), is given in Tables 41 and 42 for nature conservation and profitable agriculture respectively.

By using the scoring methods in the two tables, a particular revegetation action can be placed within the combined scoring framework in Figure 9 (page 91). Note that any intended action should be scored for both nature conservation and profitable agriculture, and the scores are added within each category. For example, a commercially prospective native species of local provenance that used water from a recharge area affecting conservation lands would attract a score of +2 for nature conservation and +2 for profitable agriculture. Funding would therefore be on a one for one basis, on a community to individual sharing arrangement. Further examples can be readily worked out using Figure 9 (page 91).

Using this diagram five cost-sharing zones are defined. These are as follows:

Zone 1: revegetation actions within this zone are so profitable that, irrespective of their nature conservation benefit, they should not attract community funding. An example would be plantations of *Eucalyptus globulus*. Note, however, that during the development phase such plantations would have attracted (and did) community resources.

Zone 2: revegetation actions within this zone are beneficial to both nature conservation and profitable agriculture. Cost-sharing should therefore be according to relative benefit. For example, an item scoring "3" under nature conservation and "2" under profitable agriculture should be funded in the ratio of 60% by community and 40% by the individual land manager.

Zone 3: revegetation actions within this zone are negative to agriculture, and would therefore generally attract funding from community sources.

Zone 4: revegetation actions within this zone are detrimental to both land use goals, and should not be permitted.

Zone 5: revegetation actions in this zone, given their negative impact on nature conservation, should be discouraged or, for most negative items, prevented.

The scheme as proposed, if accepted (and as adjusted) by all stakeholders, would provide a simple system of cost-sharing for those areas where the priority land uses are profitable agriculture and nature conservation.

The further development of this and alternative proposals during phase II will be undertaken by agencies at their cost, and will form part of the agency contribution to the project.

Table 41: Scoring for nature conservation

Criterion	Score
Revegetation using local or regional plants in a way that provides an important resource for a locally threatened species.	+4
Revegetation incorporates multiple species of local provenance that are not harvested.	+3
Revegetation incorporates multiple species of regional provenance that, if harvested, are harvested sequentially so that at least part of the planting is able to flower and set seed each year after maturity of planting occurs.	+2
Revegetation utilises a species of local or regional provenance	+1
Revegetation uses water throughout the year, and thus contributes to re-charge control in a way that helps to protect nature conservation estate.	+1
Revegetation contributes to control of eutrophication affecting conservation estate.	+1
Revegetation has no positive or negative effects on nature conservation	0
Revegetation is a nuisance weed of agriculture or conservation estate, but readily controlled.	-1
Revegetation is a nuisance weed of agriculture or conservation estate, moderately invasive, but readily controlled.	-4
Revegetation is a weed of agriculture or conservation estate, highly invasive and/or difficult to control.	-5

Table 42: Scoring for profitable agriculture

Criterion	Score
Provides commercial return - that is, revegetation is already a commercially viable industry (eg, blue gums in the high rainfall zone).	+4
Revegetation provides a useful fodder source (eg, tagasaste)	+3
Revegetation provides a resource for a commercially prospective industry (eg, oil mallees)	+1
Revegetation uses water throughout the year, and thus contributes to re-charge control.	+1
Revegetation uses water that is accumulating in a discharge area, or potential discharge area.	+1
Revegetation protects a highly erodible site	+1
Revegetation helps prevent eutrophication of farm water resources.	+1
Revegetation provides none of the above benefits, but does not involve arable land or pastoral land.	0
Revegetation provides none of the above benefits, and uses arable land.	-2
Revegetation is a nuisance weed of agriculture.	-3
Revegetation is a nuisance weed of agriculture and highly invasive or difficult to control.	-5

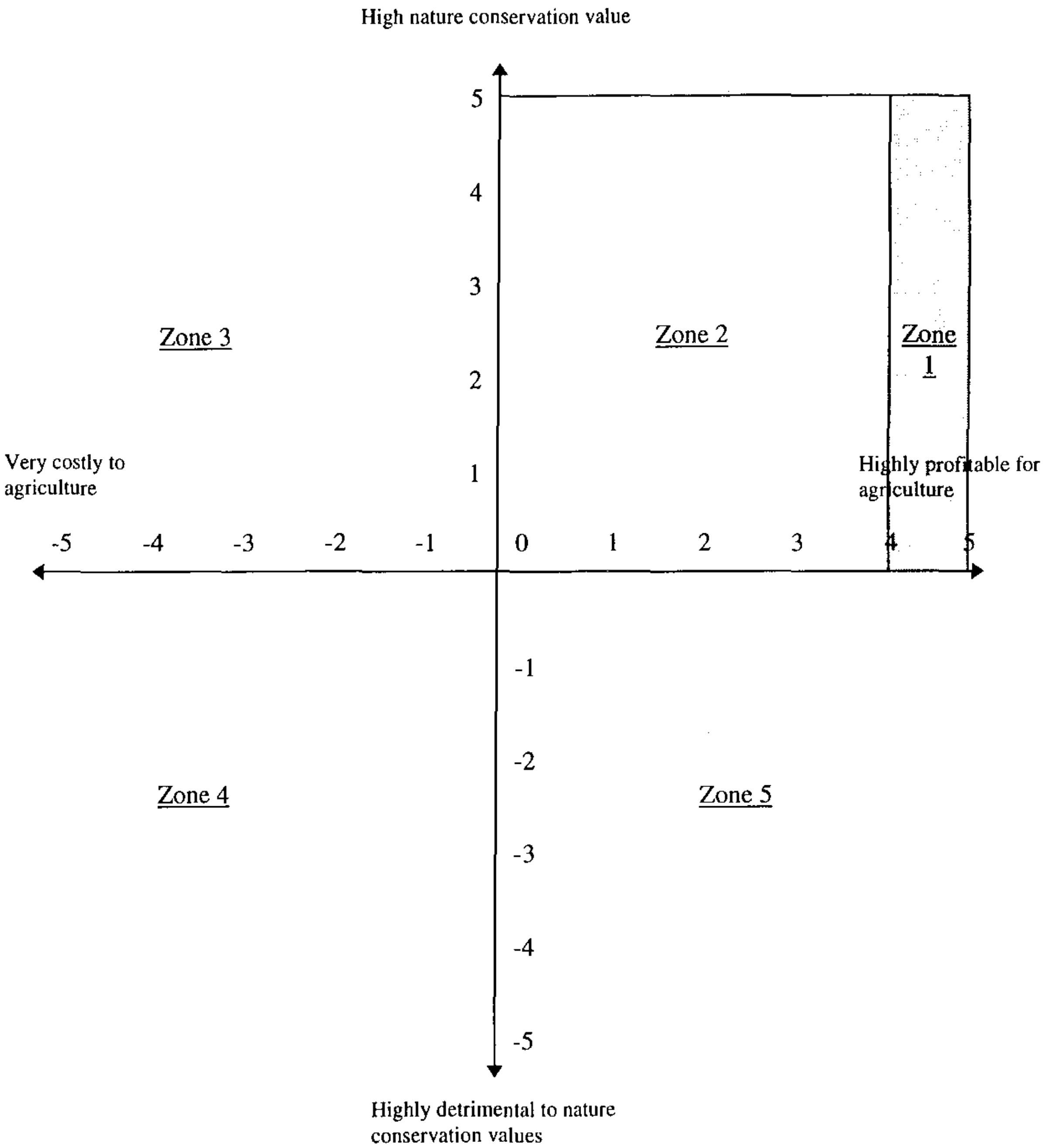


Figure 9: Cost-sharing for revegetation. Each of the zones in the above diagram implies a different mechanism for cost-sharing. Revegetation falling within zones 1, 4 and 5 would not attract community funding. Revegetation within zone 2 would be on a share basis that reflects contribution to land uses. Within zone 3, community would meet all or most costs. See text for a full explanation

IMPLICATIONS FROM PHASE I OF THE DONGOLOCKING WORK

by Ken J. Wallace

The Dongolocking work to date has two important implications for strategic natural land management:

- It highlights the importance, and difficulty, of developing useful goals and planning their implementation at an appropriate scale; and

- An approach to planning nature conservation in rural areas is elaborated. To fully develop this approach requires a range of new projects and investigations.

Both these matters are dealt with below.

Goals and Scale

Too often land management planning processes develop goals that fall into one, or both, of the following categories:

1. *Broad strategies, rather than goals, that have no clear outcomes.* For example, the goal of "to protect and enhance the natural environment .... by increasing the protection and management of remnant native vegetation". While a worthy strategy, it provides no concrete goal, and no indication of what is to be achieved. For example, if protection is to be increased, then by how much? Just a little bit? Sufficient to prevent changes in biotic composition, and if so at what scale?

2. *Worthy goals whose implications are poorly understood.* For example, "to maintain biodiversity and conserve native species in ...." While this is at least a goal, it is generally used without any understanding of the resource implications or likelihood of success.

In developing this project we, too, have had difficulties in developing a meaningful conservation goal. The six alternative goals outlined on pages 2 and 5 should provide planners in rural areas with a basis for selecting an appropriate goal for their catchment group or similar geographic unit. It would help groups that seriously wish to pursue nature conservation to work through these goals and ensure that they are clear about the on-ground outcomes they want, and what constraints there are. A stated timeframe for goals and probability of achieving them are also important if for no other reason than to remind stakeholders that all systems are dynamic - achievement of few goals is guaranteed.

Furthermore, there is commonly confusion about the scale at which a goal(s) is to be applied. The management scales used in this project are described on page 19. It is important to match management goals with an appropriate scale for action. To clarify this issue, the nature conservation management undertaken by CALM in the Wheatbelt Region is described in Table 43 (page 94).

This table shows how the various nature conservation goals are tackled by CALM regional officers at a range of scales. The same matrix could be used to describe the application of management by other groups - such as catchment groups or regional groupings.

However, there are other important scales for planning natural land management. While that described above has particular value for discussing nature conservation outcomes, management scales are often driven by administrative boundaries, and other boundaries that do not necessarily match biological boundaries.

The importance of matching goals, strategies and administrative planning scales is clear from Table 44 (page 95). This table outlines tasks achievable for a range of goals at various, commonly used administrative scales. It is a simplified model based largely on personal experience. Points that emerge are that:

- To achieve goals requiring action across two or more "regions" - such as the protection of endangered species or the development of new industries based on woody vegetation - the State scale of planning and action is very important;

- Unless the boundary of a "regional" grouping is congruent with bio-regional and land use

Table 43: Interaction of goals and scale - management by Department of Conservation and Land Management (Wheatbelt Region)

MANAGEMENT GOAL	SCALE OF ACTION				
	Individual	Population	Specific Area of Bushland	Landscape	Bioregion and Larger Scales
Do nothing	x	x	x	x	x
Don't make the current threats to nature conservation any worse	x	✓	✓	✓	✓
Slow the inevitable decline in biodiversity	x	x	✓	✓	✓
Take positive steps to conserve specific elements (usually species or communities)	x (although does happen with a few critically threatened species)	✓ (threatened and commercial only)	✓ (selected, eg Toolibin Lake)	✓ (selected, includes threatened species and communities	✓ (selected, includes threatened species and communities)
Conserve all natural populations in an area	na	na	✓ (selected)	✓ (selected)	x (at this scale aim is to conserve representative populations, not all populations)
Reconstruct, including re-introductions	✓	✓	✓ (mammals at Dryandra Woodland)	✓ (mammals in Lake Magenta NR)	x

✓ = *management actions are specifically applied at this scale.*

x = *management actions are not specifically applied at this scale, however, actions at larger scales may assist goal achievement at this scale.*

na = *application of the goal is not applicable at this scale.*

boundaries, planning at the regional scale is difficult, and will tend to be of a "motherhood" type. However, in practice this scale is the smallest (at least in Western Australia) at which there can be regular meetings between a wide range of "senior" stakeholders. Therefore this level is very important for liaison, information flow, and consensus building. These functions operating at a broader level tend to be focused away from the "grass roots", while at smaller scales they are resource demanding and unlikely to involve the senior community and agency representatives available at a regional level. It may seem desirable to make administrative and biophysical boundaries congruent. However, to do this ignores the complexity of both biophysical and cultural boundaries, and the fact that boundaries to achieve specific goals will vary. Therefore it is preferable to design boundaries for a particular goal, then identify and plan for the consequences. Dongolocking shows a number of boundary "dilemmas". While the remnants in the study area are a logical management unit, they cut across three local authority boundaries, several sub-catchment boundaries, and three social groupings with boundaries that are not entirely consistent with other divisions. Despite these complications, the study area is still logical from the viewpoint of nature conservation. However, management strategies must take into consideration the constraints imposed by other boundaries; and

- Planning effective on-ground works will generally involve local projects with 15-20 (preferably less, some landcare officers prefer to work with no more than seven) landholders

Table 44: Goals, planning scales and actions

Planning Goal	Planning outcomes achievable at a State level.	Planning outcomes achievable at a "regional" level.	Planning outcomes achievable at a district level.	Planning outcomes achievable with groups of <20 (ie farmers plus agency staff).
To conserve threatened species and communities	• Criteria for identifying endangered species and communities. • Development and monitoring of policy and management guidelines. • Decisions on funding priorities.	Liaison, consensus building, political support, lobbying for financial support, information distribution. All these, except the latter, achieved at the group level.	Operational planning and implementation, monitoring of populations and management effectiveness.	On-ground implementation for specific endangered populations or communities.
To integrate revegetation to achieve land and nature conservation	• Research and integration of information. • Broad policy and guidelines. • Decisions on priorities for funding.	Re-development of State level plans at this scale is not productive unless regional, bio-regional and land use boundaries coincide. Therefore major planning tasks here will be as above. Also, regional groups can be important for allocating funds to local groups and establishing priority "themes" and issues.	Planning involves specific projects that reflect State priorities and local circum-stances. Some on-ground implementation will occur. Generally, operational expertise will exist at this level, and this will feed the planning needs at the smaller scale.	Planning and implementation of on-ground works is only likely to be effective at this scale given the enormous range of local conditions. Integration of very different goals at this scale generally depends on satisfactory planning assistance developed at the previous scale.
To develop new industries based on perennial native species	• Criteria for identifying prospective species. • Decisions on priorities for funding. • Market analysis and other R&D. • Stakeholder liaison involving industries, etc.	Liaison, consensus building political support, etc as described above. For this goal, regional groups would also provide a forum for comment and a means for ensuring sufficient regional consideration in projects.	Planning involves specific projects that reflect State priorities and local circumstances. On-ground implementation often occurs, for example, district plantation operations.	Planning and implementation of specific projects also occurs at this level, particularly for projects integrating a wide range of goals. Specialist expertise often from district level.

with a common interest. Larger farmer/agency groupings than this are unlikely to have either sufficient common ground or socio-cultural compatibility to work effectively. This is particularly so where project boundaries are based on catchments, as these often cut social boundaries. However, these limitations would not necessarily apply to single projects involving on-ground implementation of a "simple" goal, for example, the construction of a very long corridor.

It is clear from the foregoing discussion that the goal selected for the Dongolocking project demands a management scale of at least the landscape level. The actual size of the landscape chosen for Dongolocking is a compromise between two opposing forces:

1. The need to maximise the area treated with nature conservation works to maximise the probability of achieving the project goal; and

2. The need to keep the project sufficiently small so that project planning could effectively integrate and involve stakeholders, and allow for effective implementation of on-ground works.

That the final study area is a compromise is shown by the fact that it would, from a biological viewpoint, be better to have a slightly larger area, and from a socio-cultural viewpoint a smaller number of stakeholders would have been better.

In concluding this section, it is valuable to summarise the planning approach at Dongolocking. This approach has or will involve:

1. Selecting a "polygon" of particular nature conservation interest where the goal is to conserve, with a high probability of success, the remaining native biota (although note that the scale selected for the polygon may preclude effective management of some wide-ranging or migratory species). At Dongolocking the polygon of interest is based around a very important set of nature conservation reserves. The Toolibin Lake Recovery Catchment, some 15 km to the north-west, is also a nature conservation polygon. However, it is being managed for a narrower set of conservation objectives.

2. Establishing clear goals for the management of each polygon. These objectives, and the characteristics of the polygon, will determine how planning proceeds.

3. Defining the threats to the goal(s), and how these may be combated. Select focal species (see page 59) that are most sensitive to these threats.

4. Determining which other land uses significantly affect achievement of this goal, and what the threats are to these land uses. Planning must deal with the issues, both the synergies and antagonisms, that exist between the land uses. Development of the synergies are particularly important, and should be a priority.

5. In cases like Dongolocking, where there is a specific goal focused on conserving the total polygon biota, or a significant portion of it, then the selection of focal species and implementation of the process defined in "Nature Conservation at the Landscape Scale - Adequacy of Habitat" should be followed. It is also helpful to prepare a probability table defining the likelihood of success (see Appendix).

6. At the same time as the nature conservation needs of the landscape are defined, the stated needs of landowners should be described along with the elements needed to construct a sustainable landscape. These needs must then be integrated through planning at both the landscape and other management unit (for example, reserve or freehold farm unit) scales. At Dongolocking, we have concentrated on the needs of biodiversity, hydrology, and erosion control (the latter two to be dealt with in phase II). However, the need for new profitable elements in the agricultural system, particularly those that integrate well with other needs, will also been an important consideration.

7. The planning phase of the project will be complete when an on-ground implementation plan has been adopted by stakeholders and on-ground work has begun. However, the total project, if effectively implemented, will not be complete for 50 years. On-going management will be required over this period, and the success of the project may be judged at that point. Given that a number of freehold properties are likely to change hands over this time frame, the need for on-going agency commitment is stressed.

The seven steps described above may also be readily adapted for use with single, large conservation areas. Apart from the biological advantages of doing this, it is a useful way to integrate management with surrounding land uses.

The Dongolocking case study is a project within an agricultural landscape that, while focused on nature conservation, recognises that conservation outcomes can only be achieved through actions that are effectively integrated with the goals of other land users. The Project Steering Committee believes that this project has, to date, provided a valuable model for nature conservation planning in agricultural landscapes. However, it is important to develop the management polygon concept in ways that enable it to be effectively implemented with minimum resources.

Development of the Management Polygon Concept

If it is accepted that management polygons, such as that at Dongolocking, are an important strategy for conserving biota in agricultural areas, the question arises as to how the approach might be extended to other areas in the agricultural zone. To successfully extend the model requires answers to the following questions:

1. How best can we select management polygons?

2. How do we improve the selection of focal species and the prediction of their habitat needs? In relation to the latter, it is vital to improve predictions of habitat required for viable populations. It is also essential to investigate how requirements change across climatic and vegetation zones.

3. Once a polygon is being successfully managed, what is the next step to improve its contribution to conservation? For example, should we make it bigger, or connect it to other polygons? And how important are such connections for migratory and nomadic species, or for more stable metapopulations, or for other species with very large area needs (such as raptors)?

4. How could community groups, such as focus catchments, use the polygon process, and how can we make the process simpler, and far less demanding of resources?

Each of the four questions listed above are developed further below.

Selecting and Managing Polygons

Where conservation of the State's biota is the goal, selection of priority polygons can be driven by nature conservation values represented in competing areas. Such polygons should be selected at the State level, and CALM should take the lead role in this process. However, it is important that cultural issues, likelihood of local adoption and other matters be taken into consideration. There is no theoretical upper limit to a polygon size on conservation grounds, however, they will be limited in size by the need to work at a scale where the number of land managers involved allows group coherence and effective on-ground implementation. It was suggested previously that this is 20 or less land managers and no more than 50 000 ha.

Improving the Focal Species Concept

Perhaps the greatest limitation of the focal species concept is that calculated needs, in terms of habitat patch size, are not sufficiently linked to population viability. While this latter step will always be difficult, the current situation could be improved through further case studies and strategic surveys as described in (a) and (b) (page 98). This approach should also provide the generalizations needed to allow the focal species approach to be generally applied throughout the agricultural area.

Another important limitation of the focal species approach used at Dongolocking is that it only utilises birds. The validity of using this taxonomic group as an umbrella for other species must be tested and, if necessary, other taxonomic groups added as focal species. The lack of information on other taxa should not, however, be used as a reason for delaying implementation of a landscape scale approach to nature conservation.

From work with birds, it appears that there will be a consistent list of focal species that will generally apply in the south-west agricultural zone. All that will vary will be which of the list are most at threat in a particular locality, and this will reflect to what point habitat has declined in area and condition.

Connecting and Expanding Polygons

Once a polygon has been selected, planned, and is being effectively managed, there is a question as to whether the polygon should be expanded in a concentric fashion, or connected to other polygons, or left in isolation. In reality, all three approaches are likely to be used. However, given the need to cater for migratory and nomadic species, as well as species with very large (in area) effective metapopulations - for example, wedge-tailed eagles - some form of connection across the broader landscape is likely to be important in most cases. This is an issue that should be explored further and developed into an investigation if necessary.

Use of the Polygon by Community Groups

Community groups, particularly focus catchment groups, could readily use the polygon concept provided:

i. Goals for catchment management include conservation of the catchment biota over the medium to long term. Where this is not the case, they would be better (depending on their goal) to manage along the lines suggested in

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APPENDIX – PROBABILITY OF ACHIEVING MANAGEMENT OBJECTIVE

by Ken J. Wallace

Biophysical systems are dynamic and subject to chance events that are often difficult to predict and impossible to manage. Therefore to have, as in this project, an objective that seeks to retain all the current biota for an area immediately stimulates two questions:

1. Would this probability change in the absence of management?

2. What is the probability of achieving the objective with management?

The answer to the first question is "yes". For example, we know that the quenda (*Isoodon obesulus fusciventer*) has, after reintroduction, survived and prospered with predator control, and that it disappeared without predator control. Therefore, without management there is a probability of 1.0 that at least one species would disappear from the Dongolocking study area over the next 50 years.

The second question is very difficult to answer. The probability of species extinctions in the Dongolocking area is estimated below. These estimates assume that management practices proposed in this plan, such as predator control, are implemented. Although the probabilities are based on very little data and are likely to be inaccurate, it is important to estimate the impact of threats. It is tempting to believe that if we implement management, we will achieve our goal. While crude, the estimates below emphasise that this is far from the case - there are many ways in which our management may fail. It is stressed that probability setting as attempted here is an iterative process - the probabilities must be revised regularly in the light of new information.

If more accurate figures can be produced, then there is a real opportunity to better rank threats and management actions. It will prove, then, far easier to compare "apples and oranges" and thus improve the focus, efficiency and effectiveness of management. In particular, generation of more accurate threat probabilities would make possible the use of decision-making systems such as that proposed by Main (1992).

It is stressed that most of the probabilities given in the table are educated guesses - they are indicative of the relative risk of events occurring.

Threat	Method of Calculating Probability	p*
Clearing and fragmentation of habitat	Most of the threats listed below will interact in a way that intensifies the problems related to clearing and fragmentation of habitat. 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
Fire	A very large fire burnt through the Dongolocking area in 1927. Research is inadequate, but there is no record, to date, of two such fires in one location in the western wheatbelt. Therefore assumed here that unlikely to occur more frequently than once in 200 years, and that probability of such a fire causing an extinction is 10%. 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

Threat	Method of Calculating Probability	p*
Animal disease	The probability that a new animal disease will reach the south-west over the next 50 years is estimated at 0.5 given increasing use of imported feeds that incorporate animal material, difficulty of maintaining current quarantine and import standards with available resources and increasing importation of products and international movement of people. It is estimated that the likelihood of a new introduced disease affecting fauna is reasonably low (0.1, noting the Tasmanian experience), and that the probability of any such disease causing local extinctions is low (0.2). This gives a cumulative probability (0.5 x 0.1 x 0.2) of 0.01.	0.01
Plant diseases.	The probability that a new plant disease will reach the south-west over the next 50 years is estimated at >0.5 given the likely increase in plant introductions for landcare, forage, production and other purposes. This probability would be greatly reduced if local and regional species are favoured. However, it is estimated that the likelihood of a new introduced disease or invertebrate pest adapting to native species is low (estimated 0.01). However, the probability of one of the *Phytophthora* spp being introduced to Dongolocking is reasonably high given the high probability that more people will visit the area for recreation and scientific purposes, and that many of these will be coming from areas where *Phytophthora* is present. Despite the implementation of procedures outlined in this document, the probability is estimated at 0.1 that an introduction of the disease will occur, but only 0.01 that this will result in the local extinction of any one species (*Banksia grandis*, given its susceptibility and occurrence in one small population is the most likely victim). Even if an introduction occurs, it is likely to spread slowly given the climatic conditions at Dongolocking.	0.02
Invertebrate pest	The probability of a locust plague or other similar pest outbreak over the next 50 years is very high - estimated at 0.95. The probability that this would be so severe as to result in the local extinction of a species, even where combined with another event such as fire, is estimated to be very low (0.005). Therefore the estimated probability of extinctions from invertebrate pests is considered to be negligible (0.0048). Note, however, that the control of an invertebrate pest may be an issue (see section below on inappropriate use of pesticides).	0.0
Salinity	The probability of increasing salinity resulting in the local extinction of a plant or animal in the broader Dongolocking area (within 15 km) within 50 years is 95%. For example, the only populations of *Callistemon phoeniceus* in this range will almost certainly disappear within this time period. However, the study area itself is high in the landscape. While general groundwater rise combined with landscape impediments may, if unchecked, remove species such as *Eucalyptus salmonophloia* or *E. loxophleba* within the study area, the probability of this is estimated as quite low (0.01) provided sufficient revegetation occurs.	0.01
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 1980s (eg *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 very high. The probability of a new environmental weed being introduced or expanding and displacing a native species is calculated to be 0.05. Assumptions: • rate of introductions will remain constant or increase. There is nor reason to believe that the introduction rate will decrease from that described by Hobbs. In fact, given the interest in bringing new woody species into the environment for production and landcare reasons, it is reasonable to assume that the	0.05

Threat	Method of Calculating Probability	p*
	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 exclude at least one native species within fifty years, either by direct competition or by habitat alteration is quite low (although high over, say, 1-200 years). Probability assessed to be 0.05.	
Drought or other climatic event	Within a 50 year timeframe, the probability of drought or other climatic event detrimentally affecting plants is high. For example, drought has killed some plants at Dongolocking (unpublished CALM file information), extensive but localised frost effects have been recorded near Pingelly (unpublished CALM file information) and in Victoria's mallee (O'Brien 1989), and temperature extremes may cause differential death amongst plant species (Lamont 1992). However, local extinction of a species from the study area is highly unlikely. In contrast, if an individual climatic event is combined with another event, such as a fire, extinction is much more likely. Over the timeframe chosen, such a combination is still too unlikely to be given a probability.	0
Inappropriate use of pesticides	This is most likely to occur if: • a plague, such as a locust plague, occurs, and pesticides are used at a damaging rate, or in a damaging way. This could have occurred during the 1990/91 locust plague. Such an event could cause the local extinction of an invertebrate species - estimated probability 0.005. Predators and parasites contributed to control in 90/91 (Agriculture Protection Board 1990/91). The development of an effective native parasite as a control method would reduce the probability of pesticide damage to 0. • a herbicide is introduced that is perceived as essential for successful cropping, but is detrimental to a native plant (including fungi and algae). Given the rapid increase in herbicide resistance among plants, and the temptation to introduce herbicide tolerance into crop plants (which may then become environmental weeds, or cross with environmental weeds), this scenario is estimated at 0.005. • solvents or other components of herbicides affect the reproductive success of animals. For example, the detrimental effects of surfactants on amphibians and other vertebrates (0.005). Combined probability of this category is 0.015.	0.015
Cultural values changing in a way that is even less aware and tolerant of nature conservation	For example, a cultural threat is that, in about 20 years time, rural society may be confident that they can control salinity, and that land clearing can re-commence. If this is combined with a larger human population both within Australia and within Asia, then the pressure to clear bushland for crops in the Dongolocking area will be high. This combined scenario must be seen as quite probable over 100 year timeframe, but much less likely over a 50 year period. Estimated probability is 0.01.	0.01
Synergistic effects of threats occurring simultaneously	While the synergistic effects of combining two or more of the threats listed above would be highly threatening, the unreliability of the estimates used above makes their combination highly inaccurate. Therefore, while the threat is recognised, no attempt is made to calculate it here. However, this would be essential if an accurate estimation of threats was to be made.	0
	Total	**0.2**

**p* = Probability of a single species extinction occurring within 50 yrs.*