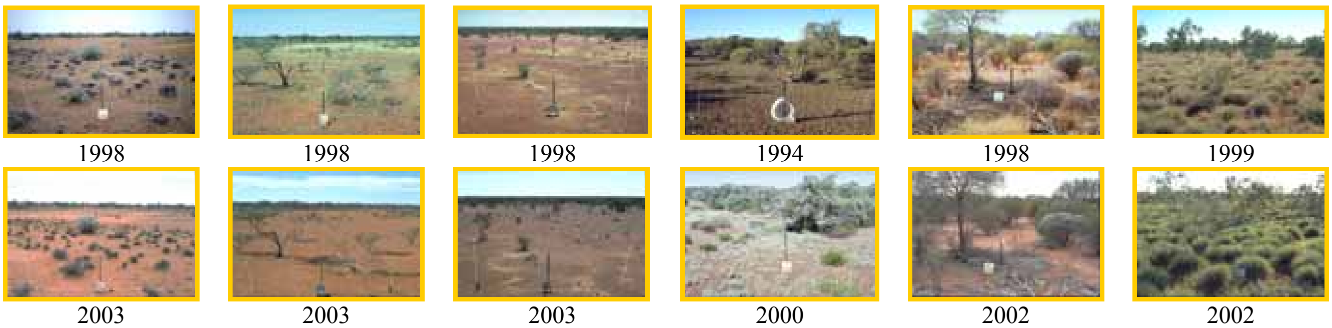
Case study of status and change in the rangelands of the Gascoyne – Murchison region

Report to the Australian Collaborative Rangeland Information System (ACRIS) Management Committee



Ian Watson, Jeff Richardson, Philip Thomas and Damian Shepherd

Australian Government

CMAE
CENTRE FOR THE MANAGEMENT OF ARID ENVIRONMENTS

Government of Western Australia
Department of Agriculture

http://www.deh.gov.au/land/management/rangelands/acris/index.html

ISBN 0642551847

Copyright and Disclaimers

Acknowledgements

A large number of people helped the authors compile this report. Gary Bastin, the ACRIS Coordinator, provided much insight, encouragement and advice on what was useful at the national scale. Gary also did a fantastic job of synthesising the mass of disparate information to come out of the pilot project reports and other data sources into a coherent national report. Members of the ACRIS management committee (past and present) provided good ideas, support and encouragement for the set of ACRIS pilot projects. Mark Stafford Smith, Annemarie Watt and Blair Wood kept the states focused on the task without unduly restricting us, while the representatives of the other states and the Northern Territory gladly shared their ideas and their draft work in a spirit of cooperation rather than competition. Many people in Western Australia willingly supplied data that were used in the report or answered various queries including Tony Brandis, Annabelle Bushell, Peter Curry, Val English, Alec Holm, Angas Hopkins, Margaret Langley, Peter Mawson, Ben Norton, Chris Olsen, Peter Orell, Hugh Pringle, Rosemary Reese, Deon Utber, Sandra van Vreeswyk and Andrew Woolnough. Josh Smith calculated which rainfall station was closest to which WARMS site. John Carter and the Aussie GRASS team generously provided modelled outputs of vegetation biomass used to help determine seasonal context. Fiona Daly provided helpful comments on a draft of the report. Wayne Fletcher and Kerry Skinner collected most of the WARMS data used.

Contents

List of Attachments

List of Figures

Attachment 1 – Figures

Attachment 2 – Figures

Attachment 3 – Figures

Attachment 4 – Figures

Attachment 5 – Figures

Attachment 6 – Figures

Attachment 7 – Figures

Attachment 8 – Figures

Attachment 10 – Figures

List of Tables

Attachment 2 – Tables

Attachment 3 – Tables

Attachment 4 – Tables

Attachment 5 – Tables

Attachment 7 – Tables

Attachment 9 – Tables

Attachment 10 – Tables

List of WARMS Photos

Executive Summary

The ACRIS pilot project in the Gascoyne-Murchison region of Western Australia showed that it was possible to use a range of indicators, from a number of disparate data sets, to address the ACRIS questions about change in rangelands. Not surprisingly, because the indicators covered such a broad range of attributes and the area is so large (nearly eight per cent of Australia), the results were mixed. There was also a large range in the data for most indicators, providing both favourable and unfavourable results. This limits the number of generalisations that can be made and also suggests that a 'one size fits all' policy response will be insufficient.

The region experienced an increased capacity for change during the period of the pilot project. This was assessed in a number of ways including the perceptions of pastoral managers, their confidence in the future, and the financial health of many pastoral businesses and a range of on-ground actions. These on-ground actions include better control of grazing animals, relatively rapid and comprehensive de-stocking during drought conditions and improved landscape and ecosystem management.

However, this increased capacity for change needs to be tempered by observations that show that the median age of 'farmers' is increasing, there are less people of working age supporting the old and the young, business management skills are generally poor, there is high turnover of leases, improvements remain in the adjustment of stocking rates to match environmental conditions and some pastoral enterprises remain unviable with poor financial prospects.

Perennial vegetation as assessed on Western Australian Rangeland Monitoring System (WARMS) sites generally showed improvement. Shrub density, cover and species richness remained the same or increased on the majority of sites. Recruitment of new plants was commonplace, being found on almost all sites and for almost all species. Much of this improvement occurred during both good seasonal conditions and poor seasonal conditions, suggesting that the negative impact of grazing was not large, except on a minority of sites.

However, the results for perennial grass species and for indicators of landscape function did not show the same improvement. Despite good seasonal conditions, perennial grass frequency declined on many of the sites. Landscape function indicators declined on many sites even though perennial vegetation indicators improved.

The potential for biodiversity conservation has also increased due to the recent acquisition of almost 4 million ha of pastoral land for inclusion in the conservation estate, an increased interest in off-reserve conservation and better control of grazing pressure. However, it is not known whether these measures will reverse the long term decline seen in many ecological communities and for many threatened or priority species.

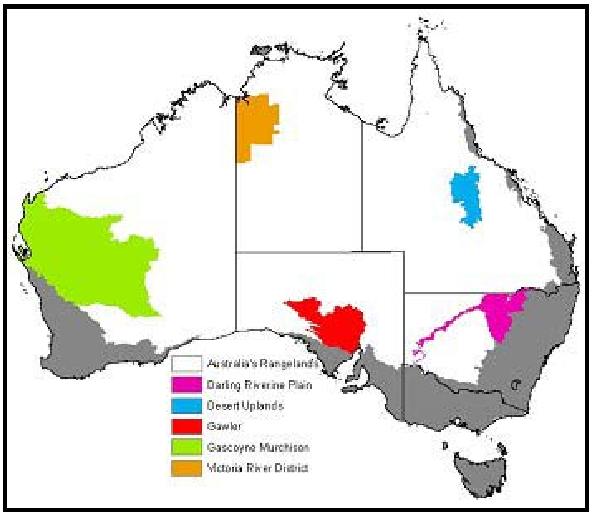
At the risk of generalising, the ACRIS pilot project has shown that in the Gascoyne-Murchison region, many of the pastoral businesses remain profitable, much of the land (although historically degraded) is showing signs of improvement, the potential for biodiversity conservation has increased and pastoral managers remain confident in their own future.

Introduction

Over the last 15 years there has been considerable interest at state/Northern Territory (NT) and Australian Government level for combined reporting of change in rangelands across Australia. However progress has been slow, partly because each state and the NT collect data in different ways and for different purposes. Some agencies have a focus on primary industry, while others have a focus on natural resource management or nature conservation. Some agencies collect good data on land condition, others put more effort into collecting socio-economic, biodiversity or land clearing data.

To begin reporting across the nation's rangelands the Australian Collaborative Rangeland Information System (ACRIS) was formed as a co-ordinating mechanism, with representatives from Western Australia (WA), New South Wales (NSW), South Australia (SA), Queensland (QLD), NT and the Australian Government.

Rather than attempting to report on 'everything and everywhere' the management committee chose to begin by producing reports on pilot regions in each jurisdiction (see map below) and addressing a limited set of five questions. The aim of this was to explore how well information from disparate data sets could be combined into a single report and then to explore how well these could be synthesised into a national report.



This report is for the Gascoyne-Murchison pilot region in WA. It forms part of a group of reports including pilot project regional reports from NSW, SA, NT and QLD, a report on socio-economic and financial indicators produced by the Australian Bureau of Statistics and a national synthesis report:
'Australian Collaborative Rangeland Information System National Synthesis of Reports from Pilot Regions' by Gary Bastin and members of the ACRIS management committee, 2005.

These reports, and more information on ACRIS, can be found at
http://www.deh.gov.au/land/management/rangelands/acris/index.html

The five questions posed by the ACRIS management committee were;

1. What is the change in critical stock forage productivity?
2. What is the change in native plant (and animal) species?
3. What is the change in landscape function?
4. What is the capacity for people to change?
5. What is the change in cover?

While question two was principally about native plant species, information on native animal species was included where it was available. The nominal reporting period was 1992 to 2002, although data outside this period was used for some purposes.

How this report is organised

The five questions posed in the ACRIS pilot project are addressed in the following section. The information sources that were used to address each of the questions are found in 10 attachments to this report. The report is structured in this way because some information sources were used to address more than one question and some questions were addressed by more than one information source. Attachment 11 contains the list of references cited.

Change in vegetation critical to stock productivity

The intent of this question was to focus on vegetation that is known to be important for livestock productivity as well as being known to decline in response to heavy grazing (termed Decreaser species). The Western Australian Rangeland Monitoring System (WARMS) provided the primary data to address the question, based on results from 700 shrubland sites and 71 grassland sites.

Dataset	Derived indices	Attachment
Western Australian Rangeland Monitoring System (WARMS)		2
- demography of perennial shrubs — Decreaser species (700 shrubland sites)	Density change (popn growth rate) Occurrence ratio Recruitment rate	3 3 3
- frequency of perennial grasses — Decreaser species (42 grassland sites)	Change in frequency	4

A prolonged and severe drought was experienced throughout much of the pilot region from mid 2000. Dry conditions alone should only have a small impact on the species recorded on WARMS sites, because they are long-lived and therefore drought resistant. However dry conditions and excessive grazing together have the potential for large impacts and catastrophic losses have occurred in previous droughts.

Catastrophic losses were not observed during the recent drought except on isolated sites. In fact, changes in those perennial species most related to stock productivity were generally positive in the pilot region, although undue grazing pressure had a negative impact on some sites, particularly during drier conditions.

Total shrub density remained the same or increased on 70 per cent of sites. For those sites which experienced above average seasonal conditions, there was little difference between Decreaser species and other species. However, under average or below average seasonal conditions the decline in Decreaser species was greater than for Increaser or Intermediate species. The difference in response between species types suggests that grazing had a negative impact during the drier periods. However, this negative impact was not found on all sites. For example, under below average seasonal conditions there were still 20 per cent of sites in which the density of Decreaser species increased by at least five per cent. This is 'good news' given the severity of the drought in the Murchison and Yalgoo bioregions. Of more concern is that despite above average conditions, the frequency of Decreaser grass species declined by at least 10 per cent on almost one third of grassland sites.

Seventy percent of Decreaser species were found on more sites at reassessment than at installation, suggesting that their local distribution had increased. This was a lower percentage than for Increaser or Intermediate species. However on average, Decreaser species were found on 10 per cent more sites at reassessment — a similar increase to Increaser and Intermediate species. These are mixed results. Clearly a high percentage of Decreaser species increased their local distribution, although there is evidence that without grazing this might have been higher.

Across the region recruitment of Decreaser species was common, even on those sites that had experienced below average seasonal conditions.

Change in native plant (and animal) species

The intent of this question was to explore how well ACRIS could report on biodiversity, recognising that the state and NT pastoral monitoring programs were not originally designed to do so and that there was no wide-area biodiversity monitoring system operating in any of the jurisdictions. While the focus was on native plant species, the question was expanded to include animal species where information was available. The primary data sets were WARMS, the Department of Conservation and Land Management's (CALM's) recent biodiversity audit and information on changes to the conservation estate and potential improvements in off-reserve conservation within the pilot project region.

Dataset	**Derived indices**	**Attachment**
WARMS		2
- demography of perennial shrubs (700 shrubland sites)	Density change (popn growth rate) Occurrence ratio Recruitment rate Species richness	3 3 3 3
- frequency of perennial grasses (71 grassland sites)	Change in frequency	4
Additions to the conservation estate	Area of land or percent of IBRA available for reservation	7
Areas nominated for exclusion in 2015		7
Evaluation of Ecosystem Management Unit (EMU) project		7
CALM biodiversity audit	Numbers of species, communities or ecosystems in various conservation categories	9
Permanent watering points	Area of each land type at varying distance to water Change in distance to water since World War II	10 10

The results from WARMS were generally favourable when summarised across the entire pilot region and all shrub species, at least on those areas represented by the monitoring sites[1].

Shrub density remained the same or increased on 70 per cent of sites and on only 16 per cent of sites did shrub density decline by more than 10 per cent. When considering individual species, 87 per cent increased in density and only seven per cent declined by more than 10 per cent.

The majority of species (82 per cent) were found on more sites at reassessment than at installation, suggesting that their local distribution had expanded. The majority of sites (80 per cent) had the same or an increased number of species at reassessment, i.e. species richness increased. Recruitment of new individuals, critical for population maintenance, was found on almost all sites and for almost all species.

[1] This is an important caveat when considering the use of WARMS data to report on changes in biodiversity. WARMS site locations are deliberately biased to represent vegetation important for pastoral purposes and do not represent restricted habitats or other areas such as wetlands which may be important for biodiversity conservation.

While these were generally good results overall, less favourable results were found on sites that experienced a drought, principally in the Murchison and Yalgoo areas. In these areas, there was evidence that grazing had a negative impact during the drought, since Decreaser species were more adversely affected than Increaser or Intermediate species.

Results for grassland species were more mixed. Despite above average seasons the frequency of perennial species decreased by more than 10 per cent on almost a quarter of sites. On a sub-set of 40 sites that had been sampled three times, 28 (70 per cent) of them showed an increased frequency during at least one reassessment interval.

CALM's recent biodiversity audit summarised information on the status of both ecosystems and species at the level of sub-bioregion. As its title suggests, the work is an audit rather than monitoring of recent change. Where change information was provided, the timing of change was typically at some unknown period since European settlement, rather than the recent change identified by WARMS.

Within the pilot project region there are 18 wetlands of national significance and 18 wetlands of sub-regional significance. There is only one endorsed Threatened Ecological Community[2] but a further 112 ecosystems are considered at risk.

At least four mammals are extinct from the region with 13 others considered threatened or Priority 1 or 2. Of the 48 threatened and priority one and two vertebrate species populations (mammals, reptiles, birds and fish) only 15 per cent are considered in good condition, 29 per cent are degraded and 48 per cent are considered fair. Only four per cent of these species are considered improving whereas the trend for 52 per cent is declining or rapidly declining. For all the vertebrate groups combined, feral animals are considered an important threatening process in 29 per cent of cases; grazing pressure (22 per cent) and changed fire regimes (20 per cent). There is only one instance of improving trend in the status of a threatened or priority species, the mallee fowl.

Of the 3,557 vascular plant species in the region, 333 are considered threatened or of conservation priority. A sub-set of these (threatened or priority 1 or 2) was used to develop an understanding of condition and status. While the condition of 59 per cent of this sub-set is unknown, 18 per cent are in good condition and 22 per cent in fair condition. The trend in condition is largely unknown for 70 per cent but 17 per cent are thought to be in decline and 11 per cent are static. Grazing pressure from livestock and feral animals, exotic weeds and altered fire regimes are all thought to be responsible.

The potential for biodiversity conservation in the pilot region has been significantly enhanced by the acquisition since 1998 of almost 4 million ha of pastoral leasehold land for inclusion in the conservation estate, although the acquisition is biased towards land of lower pastoral productivity and there are about 110 of 259 vegetation associations that remain to be included in the estate. Despite this, there has been a large increase in the number of vegetation associations represented. This increased from 74 in 1998 to more than 144. About 18 per cent of the vegetation associations

---

[2] CALM uses a standard set of categories to describe the status and priority of ecological communities and species (see Table 9:20, Attachment 9).

now have at least 10 per cent of their area represented. There are also a number of areas on pastoral leases that have been nominated for exclusion in 2015.

Three leases have been bought since 2000 for the purposes of privately funded conservation. Two of these comprise part of an area of close to 1 million ha which is increasingly being managed for conservation. This area sits across the junction of four bio-regions (Avon, Coolgardie, Murchison and Yalgoo).

The extent of off-reserve conservation on commercial pastoral leases is difficult to quantify but it is known to have improved during the time of the Gascoyne-Murchison Strategy, partly through the work of the Ecosystem Management Unit (EMU) project.

The EMU project worked with managers to enhance ecological literacy, improve understanding of landscape processes and ways to better manage biodiversity on-station. The project engaged pastoralists on about 65 leases, covering an area of 15 million ha. It helped put in place pastoralist management of nationally listed wetlands, management of a range of habitats containing rare or threatened flora, catchment restoration work and protection of fragile river frontage and coastal dune areas. There were 13 specific biodiversity projects implemented. At the regional scale the EMU project also worked to identify and set priorities for biodiversity conservation both on-station and as part of the reserve system.

The provision of artificial watering points by the pastoral industry has brought permanent water to much of the rangelands, favouring those species that require free standing drinking water. However, it has also allowed the negative impacts of grazing across a much larger area. On pastoral leasehold land and associated reserves, there is only one land type within the pilot region in which more than 50 per cent of the area is beyond 6 km from permanent water. Almost all the land types have less than 10 per cent of their area beyond 15 km from water. Six land types have at least 50 per cent of their area within 3 km of water. A comparison of watering points between about the time of the Second World War and the 1990s showed, that for the test area examined, the area of land within 6 km of water increased from 66 per cent to 90 per cent. A general increase in watering point density was found for all but one land type. The increase was most pronounced on highly productive and fragile systems.

Change in landscape function

Landscape function refers to the way resources (water and nutrients) move across the landscape; i.e. the extent to which they are either captured by the landscape or shed into drainage lines and lost to the system.

Assessments of landscape function are increasingly being used to report on changes in rangelands for several reasons. Firstly, they are assessments of basic function, unhindered by arguments about whether the changes observed are ‘good’ or ‘bad’, which often characterise assessments that only consider vegetation species. Secondly, they reflect the fundamental way water and nutrients are conserved in the landscape, which is a direct measure of the potential of the landscape to grow vegetation. Unfortunately, assessment of landscape function is less rigorous than assessment of vegetation because of the degree of subjectivity involved.

The WARMS data set was used to report change in landscape function, using standard CSIRO techniques. Good quality data were available from 398 shrubland sites and 47 grassland sites.

Dataset	Derived indices	Attachment
WARMS		2
- standard CSIRO Landscape Function Analysis on shrubland and grassland sites	Resource Capture Index Proportional landscape function for each site as: - stability index - infiltration index - nutrient cycling index	3 3 3

In general the results from the landscape function assessments on WARMS sites were worse than from the vegetation assessments. For example, on 69 per cent of shrubland sites and 64 per cent of grassland sites there was a decrease in the proportion of resource capturing patches on the sites, suggesting a decreased ability to trap water and nutrients. This result was largely independent of whether the sites had experienced above average, average or below average seasonal conditions.

Further work is required to tease out the contradictions between the landscape function and vegetation assessments but the relationship may depend on vegetation type or it may be that the data reflect populations of younger plants replacing old, and thereby consisting of smaller resource capturing patches.

Subjectively assessed landscape function attributes were also combined into standard indices representing stability, infiltration and nutrient cycling. These indices, particularly the latter two, tend to be more driven by recent seasonal conditions than by longer-term change in the rangelands. The stability index remained the same or increased on 51 per cent of shrubland sites and 62 per cent of grassland sites. The infiltration index remained the same or increased on 47 per cent of shrubland and 53 per cent of grassland sites. The nutrient cycling index remained the same or increased on 36 per cent of shrubland and 51 per cent of grassland sites. For all three indices the results were most favourable on sites that had experienced above average seasonal conditions and least favourable on sites that had experienced below average seasonal conditions.

Capacity for change

The capacity of managers to adapt to change is a critical indicator of their ability to address environmental issues as well as improve their enterprise viability. Capacity for change is not only important for individual managers, but also for the industry as a whole and for government. Finding consistent, time sequential data that indicates a capacity for change has always been difficult, so the ACRIS management committee deliberately left the question broad in scope, while at the same time trying to ensure at least some consistent data across jurisdictions.

Dataset	Attachment
Australian Bureau of Statistics	
- Census of Population and Housing 1991, 1996 and 2001	separate report
- Agricultural Census 2000–01	separate report
Gascoyne – Murchison Strategy reports	
- independent evaluation of the strategy	6
- benchmarking, financial advice and business review project	6
- access to commercial finance and economic overview	6
- independent evaluation of the Ecosystem Management Unit project	7
- the conservation reserve system	7
Pastoral Lease Information System	
- livestock numbers	6
- livestock enterprise	6
Draft NRM strategy	7
Pastoral lease sale data	8

There were two types of data sources used to address this question. ACRIS contracted the Australian Bureau of Statistics (ABS) to report statistics for each pilot region that could indicate the capacity for change. The ABS used data from the national census data (1991, 1996 and 2001) and agricultural census (2000–01). Each jurisdiction also used its own local information. In Western Australia, much of the source information was taken from various Gascoyne-Murchison Strategy (GMS) reports, particularly an independent evaluation of the strategy's outcomes, as well as information on pastoral lease sales and change in livestock numbers.

The ABS work showed that the median age of 'farmers' in the pilot project region had increased from 44 years in 1991 to 48 years in 2001. Furthermore, 71 per cent were older than 41 years and 23 per cent older than 60 years. These results were similar to the other pilot regions except the Victoria River District (VRD) where farmers tended to be younger. Age statistics can be used to help explain the likely desire to remain on the property, their exposure to environmental concepts and their adoption of different practices. The Gascoyne-Murchison region (like the other regions except the VRD) experienced a net loss of young people and an increasing age-dependency ratio, i.e. an increasing proportion of younger and older people compared to the working age population. Only seven per cent of the population in the Gascoyne-Murchison was employed as 'farmers' or 'farm managers'. The ABS results need to be interpreted with some caution because of the difficulty in overlapping the ABS data collection districts with the pilot region boundaries and because of the difficulty of separating the pastoral population from the rest of the population.

The evaluation of the GMS concluded that there was improved managerial capacity on about 50 per cent of the pastoral businesses in the region since the GMS began in

1998. This judgement was based on perceptions of viability, commitment to business planning, increased confidence in the future and a feeling that personal capacity to manage had improved. Importantly, 58 per cent of those managers interviewed thought that their own capacity to manage had increased. While there may have been some improvement, a financial benchmarking project within the GMS considered that business management skills in the pastoral industry were poor and that even basic tasks like record keeping were poorly managed.

There have been substantial changes to enterprises as well as shifts in enterprise type across the region over the last five to ten years. The evaluation report noted a number of management changes ranging from improved use of computers, new industries including horticulture and tourism, improved feral animal control, changes in flock or herd structure, non-traditional grazing systems and improved landscape management. There have also been substantial changes in enterprise type. Many of those stations that ran Merino sheep for wool production now run cattle and/or a range of meat sheep and rangeland goats.

Structural adjustment continues to be needed in the region. While a program of voluntary lease adjustment during the strategy was largely unsuccessful, 18 whole leases and 19 part leases (totalling nearly 4 million ha) were acquired for inclusion in the conservation estate. However, the GMS evaluation concluded that structural adjustment was still necessary and that a number of businesses remained unviable. However, viability is difficult to judge and many enterprises are now geared to receiving substantial proportions of their income from off-station activities. Information from a range of sources suggests that about 90 per cent of enterprises received off-station income and that about one in eight enterprises received more than one third of their income from off-station pursuits. This may be reflected in the prices paid recently for some of the less productive leases which were high-priced on pastoral value alone and have presumably been bought as a base for a more varied income stream than simply livestock production.

There was mixed reporting of the financial capacity of the industry. Information from a financial benchmarking project suggested that there were good levels of profitability across the region while information summarised from grant applications suggested that the financial situation within many businesses was poor. Both sets of data showed that there was large variation in financial capacity. Some businesses were managing very well and some very poorly. This large range suggests that managerial capacity and the amount of debt are primary determinants of financial health and that generalisations about the economic health of the industry need to be viewed with caution.

The capacity to manage for improved natural resource management outcomes also appears to have increased. Several examples of environmental management systems were developed during the GMS although there has been little uptake by industry. Artesian bore capping and reticulation has drastically improved the capacity to manage the underground water resource, saving an estimated 8.35 gigalitres of water per annum at the surface.

There is also good evidence of improved landscape and ecosystem management based on an independent report of the Ecosystem Management Unit (EMU) project. This project engaged with pastoralists on about 63 stations and led to a broad array of improved environmental outcomes including the relocation of watering points and fencelines, catchment restoration, improved management of wetlands and habitats containing rare and/or threatened species and a generally better understanding of how management decisions can have an impact on the natural environment.

The GMS also helped develop and fund total grazing management yards, with at least 1,350 built during the life of the strategy. This has improved the industry's ability to control grazing pressure on at least 10 per cent of the artificial watering points, affecting at least 17 million ha on 64 stations. About 170 additional watering points and over 1,000 km of new fencing also has the potential to improve grazing distribution and protect fragile landscapes.

The capacity of managers to match livestock numbers to forage supply is a critical determinant of natural resource outcomes and there is good evidence that this has improved in the region. During the drought that much of the region experienced from mid 2000 through to 2004 the total number of Dry Sheep Equivalents in six of the worst affected shires fell to about 58 per cent of the recent maximum in 1996–97. Large numbers of these stock were sold or agisted, rather than dying on-station. The percent of stock on hand that were sold or agisted in the three financial years 2000–01, 2001–02 and 2002–03 was 38 per cent, 50 per cent and 47 per cent, up from a longer term average (1981–82 to 1996–97) of 18 per cent. Losses remained close to the longer term average until 2002-03 when they climbed to 22 per cent of stock on hand. However, even these comparatively high losses were less than the losses reported during many previous droughts. Despite this improvement in managerial capacity, the assessment of the GMS financial benchmarking project was that managers did not de-stock early enough in the drought or to the extent that they should have.

In the eight year period 1997 to 2004 nearly 40 per cent of leases in the pilot region changed hands (excluding internal transfers and sales of part leases). While it is not possible to determine the extent to which this represents new owners and managers coming into the region or existing owners and managers buying and/or selling stations it does show considerable turnover in lease management, which has implications for the capacity of managers to manage recently bought leases.

Change in cover

Change in cover was included in the ACRIS work because it is a fundamental measure of how well the land surface is protected from erosion and is an attribute that is assessed by all state and NT jurisdictions, although in different ways.

Dataset	Derived indices	Attachment
Western Australian Rangeland Monitoring System (WARMS)		2
- canopy size of all shrubs on 700 shrubland sites	Change in canopy area by species and by site, based on width: - all individuals - all individuals less than or equal to 1.5 m	3
- crown cover of all woody species taller than 1 m on 71 grassland sites	Change in crown cover by site	4

WARMS data were used to address this question and cover was therefore defined as perennial vegetation cover. On shrubland sites this was measured as canopy area and on grassland sites as crown cover estimates of all woody species taller than 1 m. ACRIS also commissioned the Australian Greenhouse Office (AGO) to provide 'forest'[3] cover estimates using remote sensing for all pilot regions. Unfortunately, the AGO had difficulty in validating cover in the Gascoyne-Murchison, possibly because of the generally low cover found there, and it was unable to release the statistics to ACRIS.

Canopy area increased on 82 per cent of WARMS shrubland sites and the average increase in canopy area for each site was 50 per cent. This was due to both an increase in size of individual plants as well as an increase in the number of plants. Similar results were obtained when individuals taller than 1.5 m high were excluded in order to remove the effect of tall, relatively stable shrubs and trees such as mulga.

Nearly all species recorded an increase in canopy area. When averaged over the entire period the increase for Decreaser species was similar to Increaser and Intermediate species, suggesting that grazing was not having a large impact on cover. However, during the drought there was a disproportionate impact on Decreaser species suggesting that the impact of grazing was greatest during the dry period.

On grassland sites, crown cover of woody species increased on 71 per cent of sites and on 21 per cent of sites the cover decreased by more than 10 per cent. It is more difficult to judge change in terms of 'good' or 'bad' in grassland areas because many of the species are considered woody invaders and because fire can have a large, but often short-term, impact on cover.

[3] The AGO defines 'forest' as vegetation with 'a potential to reach a minimum 20 per cent canopy cover, 2 m in height and a minimum area of 0.2 ha'.

The Western Australian Rangeland Monitoring System (WARMS) site photo examples

The photos of WARMS sites on the following pages are provided to show examples of various vegetation types throughout the pilot project region, various seasonal histories and situations in which the site improved despite low rainfall or conversely, the site declined despite good rainfall. Several of the photos show examples of where one or several of the indicators suggested improvement, while one or several other indicators suggested decline. At least one photo is included from each of the sub-IBRAs included in the project region.

For each photo a number of indicators are included. These are expressed as the change in the indicator between Date 1 and Date 2 (indicator value at Date 2/indicator value at Date 1). Generally, a ratio greater than 1.0 can be viewed as an improvement and a ratio less than 1.0 as a decline.

Photos 1 to 10 show shrubland sites. Photo 11 is a grassland site.

Seasonal categories

Two methods were used in the report to categorise seasons – both described in Attachment 2

1. The ACRIS method of determining seasonal quality was used for standardisation within all the ACRIS pilot projects. The three categories were;
 - above average,
 - average,
 - below average.

2. Exceptional Circumstances (EC) Group method. This method was used to suit Western Australian state purposes. The sites were divided into four groups based on whether the lease was within the area submitted for Exceptional Circumstances due to low rainfall and if so, how long into the dry period the site was sampled;
 - EC Group 1 – site not exposed to the dry period,
 - EC Group 2 – site experienced low rainfall for one to two years,
 - EC Group 3 – site experienced low rainfall for two to three years,
 - EC Group 4 – site experienced low rainfall for three to four years.

Generally – sites categorised as above average (ACRIS) were EC Group 1, or sometimes Group 2; sites categorised as average (ACRIS) were EC Group 2, 3 or 4; sites categorised as below average (ACRIS) were EC Group 4, sometimes 3.

Indicators

Density, or population growth rate (see Attachment 3) is calculated as the number of individual shrubs/trees on the site (divided by area of the site for density).

Species richness (see Attachment 3) is calculated as the number of different shrub/tree species found on the site.

Canopy area (see Attachment 3) is used as an estimate of cover and is calculated as the area of a circle based on the estimated max width of each individual shrub/tree.

Canopy area less than or equal to 1.5 m (see Attachment 3) is used as an estimate of cover and is calculated as the area of a circle based on the estimated max width of each individual shrub/tree, but excluding all those individuals 1.5 m tall or taller – in order to remove the effect of tall, relatively stable shrubs and trees such as mulga.

Perennial grass frequency (photo 11 only – see Attachment 4) is calculated as the percentage of quadrats on grassland sites in which perennial grass is present.

Crown cover – (photo 11 only – see Attachment 4) is an estimate of the cover of all woody species that are taller than 1 m.

Resource capture index (see Attachment 5) is calculated as the proportion of each transect occupied by resource capturing patches rather than resource shedding patches.

Stability index (see Attachment 5) is a standard Landscape Function Analysis index that represents the ability of the soil to withstand erosive forces and reform after disturbance.

Infiltration index (see Attachment 5) is a standard Landscape Function Analysis index that provides an indication of how well water can soak into the soil, rather than running off.

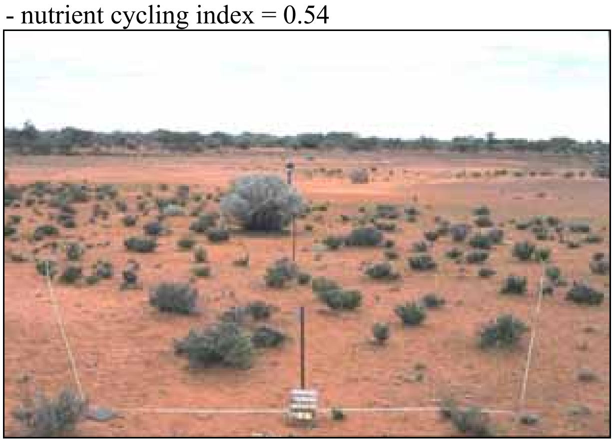
Nutrient index (see Attachment 5) is a standard Landscape Function Analysis index that shows how well organic matter is being cycled back into the system.

Photo 1. ***On this WARMS bluebush site in the Gascoyne, shrub density increased between 1998 and 2003 despite the fact that it experienced a prolonged period of below average rainfall. Other indicators, such as canopy area and the two of the landscape function indices, declined.***

Site number = 0182
Sub-IBRA = GAS 3
Vegetation type = bluebush shrubland
ACRIS seasonal quality = below average
Exceptional Circumstances Group = 4 (low rainfall for three to four years)

Ratio of attribute (Date2/Date 1)
- density (i.e. population growth rate) = 1.12
- species richness = 1.25
- canopy area = 0.72
- canopy area (less than or equal to 1.5 m) = 0.69
- resource capture index = 1.0
- stability index = 0.91
- infiltration index = 1.09
- nutrient cycling index = 0.54

October 1998

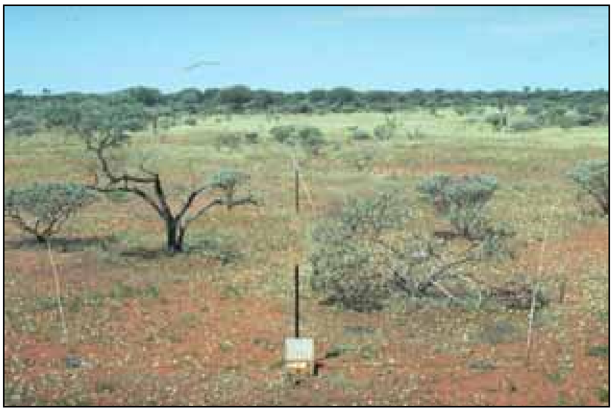


August 2003

Photo 2. ***On this WARMS stony mulga shrubland site in the Murchison, shrub density and canopy area increased between 1998 and 2003 despite the fact that the site experienced a average to below average rainfall. Species richness and two of the landscape function indices declined.***

Site number = 1034
Sub-IBRA = MUR 2
Vegetation type = stony mulga shrubland
ACRIS seasonal quality = average
Exceptional Circumstances Group = 4 (low rainfall for three to four years)

Ratio of attribute (Date 2/Date 1)
- density (i.e. population growth rate) = 1.06
- species richness = 0.86 (from 7 to 6)
- canopy area = 1.3
- canopy area (less than or equal to 1.5 m) = 1.3
- resource capture index = 1.0
- stability index = 0.93
- infiltration index = 1.07
- nutrient cycling index = 0.55



September 1998

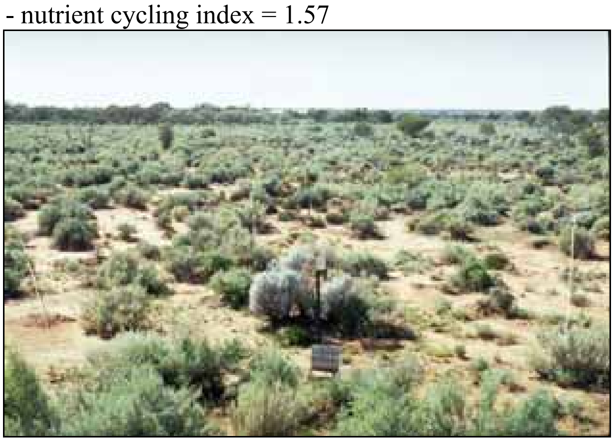
September 2003

Photo 3. ***On this WARMS bluebush site in the Murchison, seasonal conditions were good between 1995 and 2000; shrub density and canopy area increased, but the resource capture index and two of the landscape function indices declined.***

Site number = 0001
Sub-IBRA = MUR 1
Vegetation type = bluebush shrubland
ACRIS seasonal quality = above average
Exceptional Circumstances Group = 1 (not exposed to dry period)

Ratio of attribute (Date 2/Date 1)
- density (i.e. population growth rate) = 1.52
- species richness = 1.0
- canopy area = 1.31
- canopy area (less than or equal to 1.5 m) = 1.31
- resource capture index = 0.59
- stability index = 0.95
- infiltration index = 0.93
- nutrient cycling index = 1.57

May 1995



April 2000

Photo 4. ***On this WARMS hardpan mulga site in the Murchison a prolonged period of below average rainfall was experienced between1998 and 2004. All but two of the indicators declined during this period.***

Site number = 0152
Sub-IBRA = MUR 2
Vegetation type = hardpan mulga shrubland
ACRIS seasonal quality = below average
Exceptional Circumstances Group = 4 (low rainfall for three to four years)

Ratio of attribute (Date 2/Date 1)
- density (i.e. population growth rate) = 0.44
- species richness = 1.0
- canopy area = 0.52
- canopy area (less than or equal to 1.5 m) = 0.52
- resource capture index = 0.45
- stability index = 1.19
- infiltration index = 1.02
- nutrient cycling index = 0.46


September 1998


April 2004

Photo 5. ***On this WARMS mulga short grass forb site in the Murchison a prolonged period of below average rainfall was experienced between 1998 and 2004. However, shrub density and the resource capture index increased. Canopy area and two of the landscape function indicators declined.***

Site number = 1163
Sub-IBRA = MUR 1
Vegetation type = mulga short grass forb
ACRIS seasonal quality = below average
Exceptional Circumstances Group = 4 (low rainfall for three to four years)

Ratio of attribute (Date 2/Date 1)
- density (i.e. population growth rate) = 1.21
- species richness = 1.0
- canopy area = 0.87
- canopy area (less than or equal to 1.5 m) = 0.92
- resource capture index = 1.26
- stability index = 1.00
- infiltration index = 0.90
- nutrient cycling index = 0.73


November 1998

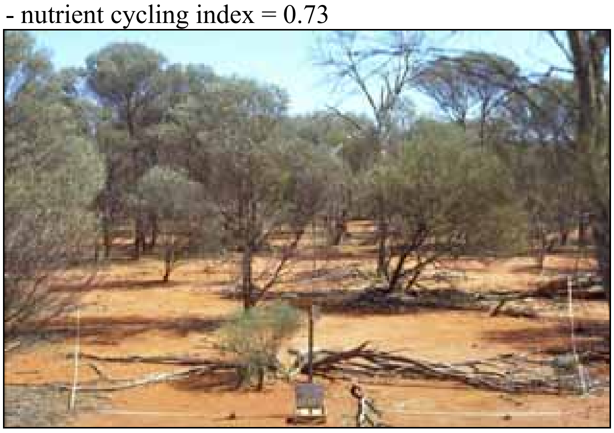

April 2004

Photo 6. ***Good seasonal conditions were experienced on this WARMS mulga chenopod site in the Gascoyne between 1993 and 1999. All the indicators increased over this period except for the resource capture index.***

Site number = 0205
Sub-IBRA = GAS 2
Vegetation type = mulga chenopod shrubland
ACRIS seasonal quality = above average
Exceptional Circumstances Group = 1 (not exposed to dry period)

Ratio of attribute (Date 2/Date 1)
- density (i.e. population growth rate) = 2.61
- species richness = 1.21
- canopy area = 1.43
- canopy area (less than or equal to 1.5 m) = 1.80
- resource capture index = 0.28
- stability index = 1.44
- infiltration index = 1.64
- nutrient cycling index = 1.92

December 1993

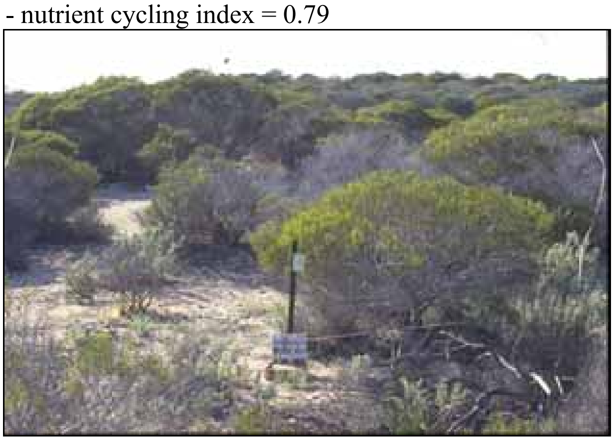
September 1999

Photo 7. ***Average to poor seasonal conditions were experienced on this WARMS coastal dune shrub site in the Geraldton Sandplain 1 sub-IBRA between 1998 and 2002. Some of the indicators increased over this period and some declined.***

Site number = 0221
Sub-IBRA = GS 1
Vegetation type = coastal dune shrub
ACRIS seasonal quality = average
Exceptional Circumstances Group = 3 (low rainfall for two to three years)

Ratio of attribute (Date 2/Date 1)
- density (i.e. population growth rate) = 0.97
- species richness = 1.11
- canopy area = 1.16
- canopy area (less than or equal to 1.5 m) = 1.33
- resource capture index = 0.79
- stability index = 1.10
- infiltration index = 0.90
- nutrient cycling index = 0.79

April 1998



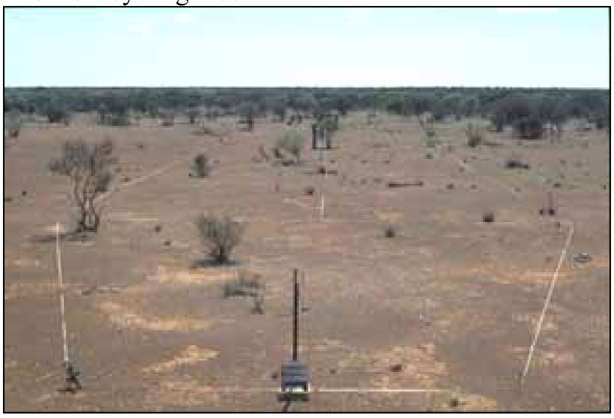
August 2002

Photo 8. ***On this WARMS mulga shrubland site in the Yalgoo region a prolonged period of below average rainfall was experienced between1998 and 2003. All the longer term indicators declined.***

Site number = 1582
Sub-IBRA = YAL 1
Vegetation type = mulga shrubland
ACRIS seasonal quality = below average
Exceptional Circumstances Group = 4 (low rainfall for three to four years)

Ratio of attribute (Date 2/Date 1)
- density (i.e. population growth rate) = 0.78
- species richness = 1.00
- canopy area = 0.60
- canopy area (less than or equal to 1.5 m) = 0.55
- resource capture index = 0.86
- stability index = 1.04
- infiltration index = 1.09
- nutrient cycling index = 0.46

October 1998



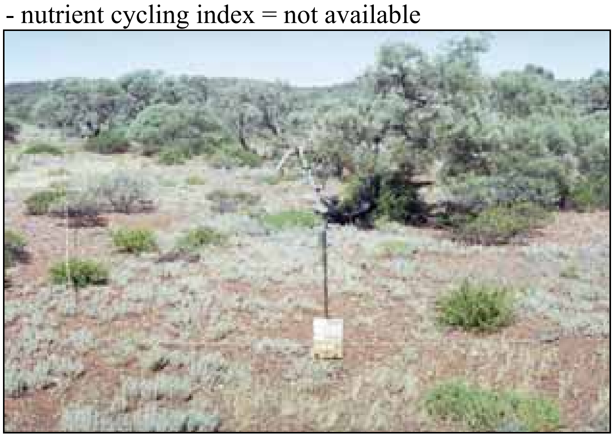
September 2003

Photo 9. ***Good seasonal conditions were experienced on this WARMS stony snakewood site in the Gascoyne. Density, canopy area and species richness all increased substantially between 1994 and 2000.***

Site number = 1433
Sub-IBRA = GAS 1
Vegetation type = stony snakewood shrubland
ACRIS seasonal quality = above average
Exceptional Circumstances Group = 1 (not exposed to dry period)

Ratio of attribute (Date 2/Date 1)
- density (i.e. population growth rate) = 1.53
- species richness = 1.25
- canopy area = 1.57
- canopy area (less than or equal to 1.5 m) = 1.86
- resource capture index = not available
- stability index = not available
- infiltration index = not available
- nutrient cycling index = not available

July 1994



June 2000

Photo 10. ***While the vegetation indicators on this Acacia sandplain WARMS site improved between 1998 and 2002, the landscape function indicators all showed a decline. This was despite reasonably good seasonal conditions.***

Site number = 1391
Sub-IBRA = CAR 2
Vegetation type = Acacia sandplain
ACRIS seasonal quality = above average
Exceptional Circumstances Group = 2 (low rainfall for one to two years)

Ratio of attribute (Date 2/Date 1)
- density (i.e. population growth rate) = 1.11
- species richness = 1.0
- canopy area = 1.12
- canopy area (less than or equal to 1.5 m) = 1.23
- resource capture index = 0.20
- stability index = 0.89
- infiltration index = 0.87
- nutrient cycling index = 0.63

April 1998

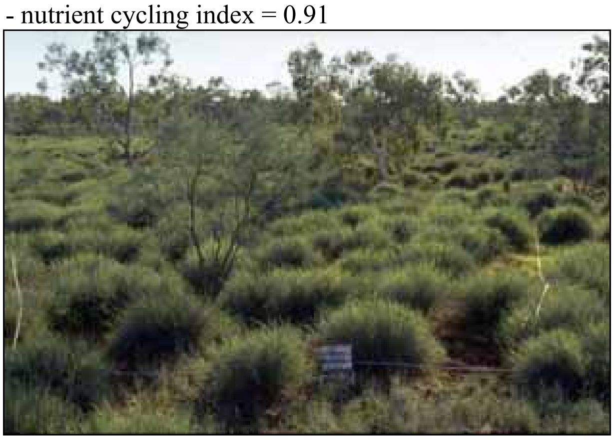
July 2002

Photo 11. ***Despite the fact that good seasonal conditions were experienced on this WARMS short bunch grass savanna site, most of the indicators showed a decline between 1999 and 2002. This is one of the few grassland sites to show decreased perennial grass frequency at both reassessments.***

Site number = 0944
Sub-IBRA = CAR 1
Vegetation type = short bunch grass savanna
ACRIS seasonal quality = above average
Exceptional Circumstances Group = n/a

Ratio of attribute (Date 2/Date 1)
- perennial grass frequency = 0.82
- species richness = 0.5
- crown cover = 1.23
- resource capture index = 0.60
- stability index = 0.89
- infiltration index = 1.08
- nutrient cycling index = 0.91

August 1999



June 2002

Attachment 1 - Description of the region

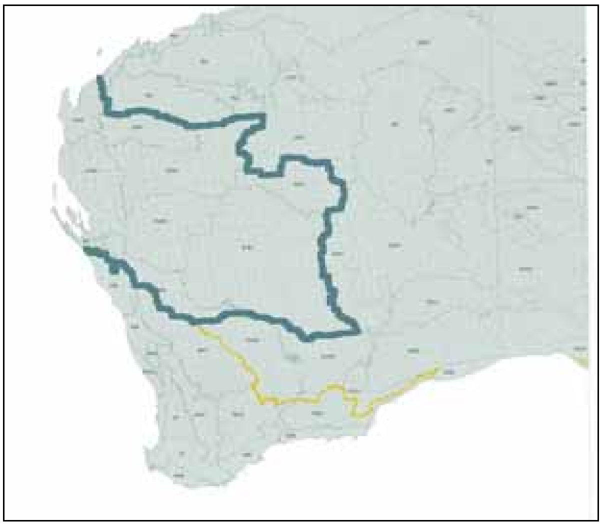
The pilot project region covers about 596,520 km^2, or 7.8 per cent of Australia (Bastin *et al.* 2005) and stretches from Exmouth in the north-west, almost to Kalgoorlie in the south-east. The main towns in the region include Carnarvon, Denham, Exmouth, Meekatharra, Cue, Mt Magnet, Wiluna and Leonora. Much of the region is pastoral land, used for livestock (sheep, cattle and goat) grazing. It is bounded to the south by agricultural (cropping) land, to the west by the Indian Ocean, to the north by the Pilbara and to the east by the arid interior, which is mostly Unallocated Crown Land. The region is sparsely populated with only 26,298 people recorded in the census of 2001 (Australian Bureau of Statistics 2004) giving an average density of one person for every 22.6 km^2. Almost 75 per cent of the population lives in towns.

The region includes much of the mulga lands of Western Australia, and the World Heritage area of Shark Bay. It includes much of the gum-belt along the south-west margin, bordering agricultural (cropping) lands. Almost all of the region can be described as arid shrublands but to the north and east the shrub vegetation is replaced by grasslands. The major rivers, which are ephemeral, are the Ashburton, Gascoyne/Lyons and the Murchison, all of which drain to the west coast. In the south-east of the region drainage is internal.

Biogeographical regions

The Gascoyne-Murchison pilot project region is made up of the complete Carnarvon, Gascoyne, Murchison and Yalgoo IBRA[4] regions as well as the Geraldton Sandplain 1 sub-region (Figure 1.1).

Figure 1.1. The Gascoyne – Murchison pilot project region (dark green line)



A large proportion of the ACRIS pilot project region is contained within the Gascoyne-Murchison sub region of the Western Australian Natural Resource Management Strategy for the Rangelands (Rangelands NRM Coordinating Group

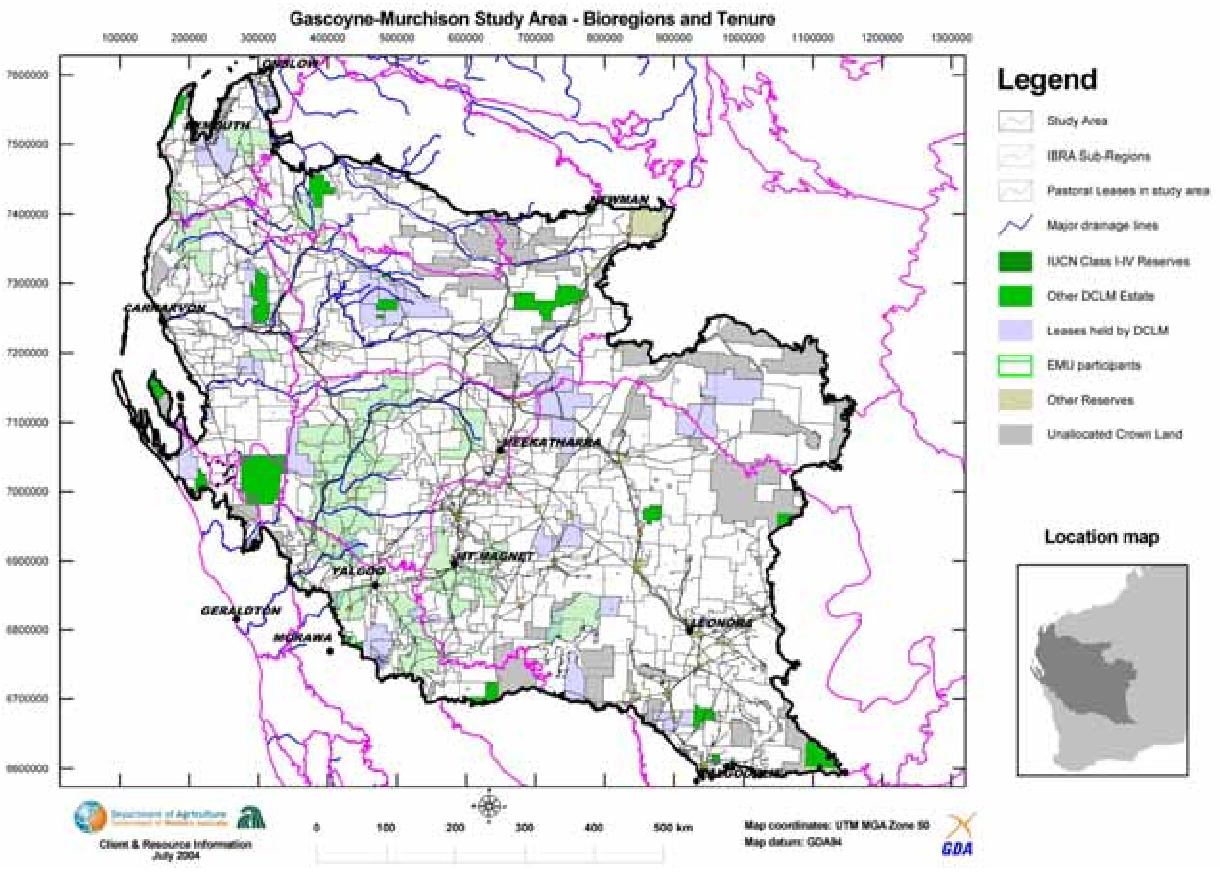
[4] Interim Biogeographic Regionalisation of Australia – based on Thackway & Creswell (1995)

2005). The Natural Resource Management (NRM) sub-regions are based on local government boundaries while the IBRA sub-regions are based on biogeographical boundaries. Therefore, the following gives only an approximate view of the overlap between the two regionalisations. Geraldton Sandplain 1, Carnarvon 1 and 2, Gascoyne 3 and Murchison 2 align with the Gascoyne-Murchison sub-region of the NRM strategy. The south-eastern part of the ACRIS region, mostly Murchison 1 and Gascoyne 2 is within the Goldfields-Nullarbor NRM sub-region, while Gascoyne 1 is within the Pilbara NRM sub-region.

Land use

By far the major land use in the region, in terms of area used and environmental impact, is pastoralism (Figure 1.2). The total area of the 292[5] pastoral leases in the region is 455,584 km^2 or 76 per cent of the area. The average property size is 1,560 km^2.

Figure 1.2. The pilot project region; land use, tenure and the conservation estate.



The pastoral industry in the region produced $83.8 million in 2000–01 (Australian Bureau of Statistics 2004) made up of sales of cattle ($38.3 million), sheep ($11.5 million), 'other livestock', principally goats ($5.8 million) and wool ($28.2 million).

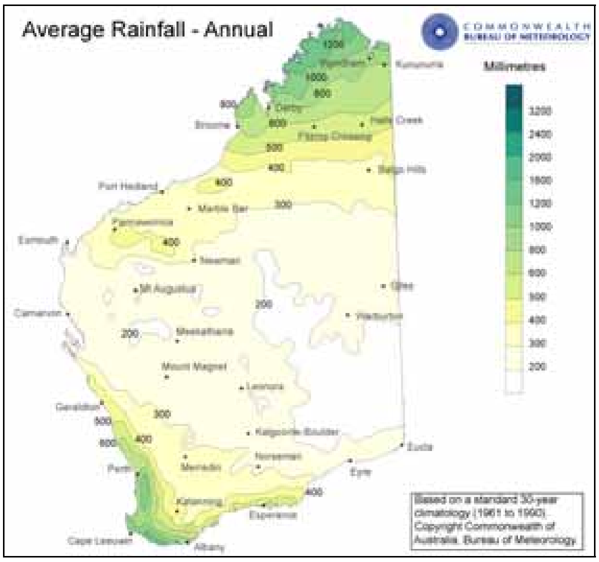
[5] This includes 18 leases recently acquired for inclusion in the conservation estate (see Attachment 7)

Climate

The region has a semi-arid to arid climate, characterised by hot summers and mild winters (Bureau of Meteorology 1998).

Average annual rainfall for much of the region is within the range of 200 mm to 250 mm. However, the extreme south-west of the region (parts of Geraldton Sandplain 1 IBRA sub-region and Yalgoo IBRA region) receives an average of 250 mm to 350 mm (Figure 1.3).

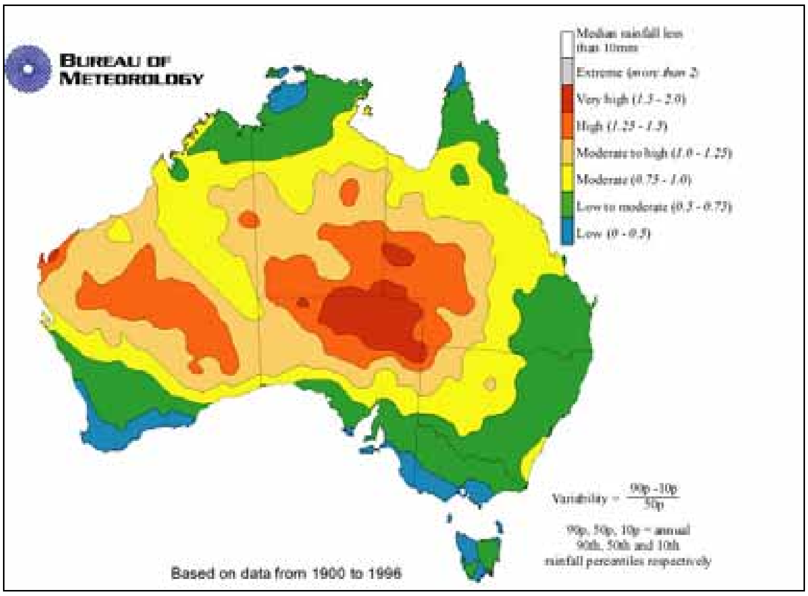
Figure 1.3. Average annual rainfall (reproduced from http://www.bom.gov.au/climate/map/anual_rainfall)



Most of the rainfall occurs in two 'seasons', May to July and January to March. However, there are distinct differences across the region in terms of rainfall seasonality. In the southern and western areas of the region, 'winter' (May to October) rainfall predominates, while summer rainfall predominates in the north and east of the region. The proportion of rainfall that occurs during winter ranges from less than 30 per cent in the north-east to 80 per cent in the south-west (Bureau of Meteorology 1998).

Average annual rainfall variability ranges from moderate to very high for much of the region (Figure 1.4). Those areas that record more summer than winter rain tend to also have a higher rainfall variability.

Figure 1.4. Average annual rainfall variability (reproduced from http://www.bom.gov.au/climate/averages/variability.shtml)



Attachment 2 – The Western Australian Rangeland Monitoring System (WARMS) – background, species categories and seasonal groupings

The Western Australian Rangeland Monitoring System (WARMS)

Much of the following was taken from Watson et al. (2001) and Watson and Thomas (2002).

WARMS provides an indication of change in pastoral rangelands at broad-scales, using a set of representative, point based sites on which attributes of soil and perennial vegetation are recorded.

The primary purpose of WARMS is to inform parliament, its agencies and the community about changes in perennial vegetation and landscape function of Western Australia's pastoral rangelands at the regional to state scale. WARMS has been developed to provide information on change, or trend, in rangelands, rather than on range condition *per se*.

WARMS is designed to report at the vegetation type or regional scale, rather than at the lease scale. It consists of a set of about 1,600 fixed sites (numbers fluctuate slightly from year to year), located on representative areas of pastoral land in Western Australia. Most leases, of viable size, have at least one WARMS site on them and on average there are about three sites per lease. These sites are maintained by the Department of Agriculture, largely for purposes related to government, although individual sites are increasingly being used to provide context information at the lease scale.

There are two different types of WARMS site. Throughout the Kimberley, the Pilbara and on some areas south of the Pilbara, grassland sites have been installed. Shrubland sites are used throughout the area south of the Kimberley, particularly south of the Pilbara. Attributes related to perennial vegetation dynamics and landscape function are recorded on both grassland and shrubland sites. On grassland sites, the frequency of all perennial species is assessed in quadrats and an estimate is made of crown cover of woody perennials. On shrubland sites, a direct census is used, the demography and maximum crown dimensions of all shrubs are recorded. Standard photographs are taken at both types of sites. The aim is to reassess grassland sites on a three year cycle; shrubland sites on a five or six year cycle.

In the ACRIS pilot project region the 785 shrubland sites were installed between 1993 and 1999; the 71 grassland sites between 1994 and 2001.

The conceptual basis for WARMS relies on the belief that the health of the perennial vegetation is a good indicator of the health of the rangelands more generally (Holm et al. 1987; Hacker et al. 1991) particularly when viewed from a pastoral perspective. Perennial shrubs are routinely used to help 'read the rangeland' (Burnside et al. 1995) as they provide important indicators of other rangeland attributes relating to landscape function (Ludwig et al. 1997). Perennial vegetation is, of course, an important component of rangeland ecosystems in its own right.

Resource surveys (e.g. Payne et al. 1987), grazing trials (e.g. Watson et al. 1997), observational studies (e.g. Hacker 1984) and various reviews (e.g. James et al. 1999) have consistently shown that the population dynamics of perennial species are affected by livestock grazing. Under excessive grazing, populations of susceptible species decrease due to a combination of reduced recruitment and increased mortality. Moreover, the composition of vegetation assemblages change over time as susceptible species decrease and 'woody weeds' increase.

Therefore the study of the population dynamics and species composition of the perennial component of the vegetation provides a useful indicator of broader changes in the rangelands used for livestock production. On WARMS Shrubland sites the health of the perennial vegetation is determined by recording the population dynamics of shrub species and by recording the maximum canopy width and height of each shrub.

The species recorded are those that typically survive for at least five to ten years and have a more or less permanent above ground canopy. These pragmatic limitations were adopted because of the need to locate individual shrubs at each recording irrespective of time of year and because the reassessment interval is typically five or six years. The majority of shrub species in the arid shrublands survive for at least five to ten years.

Site stratification

WARMS sites were only installed on land held under pastoral tenure, although on some leases the tenure has reverted to Unallocated Crown Land when acquired as part of the future conservation estate. At the regional level sites were allocated to WARMS vegetation groups based on an index of pastoral productivity, fragility and areal extent. The WARMS vegetation groups were derived from a combination of those described during the Range Survey process (e.g. Payne et al. 1987; Pringle and Payne 1997) and those described by Beard[6]

Sites were then nominally allocated to individual leases in order to distribute them across the region, in line with the regional stratification. A number of conventions were derived for allocating numbers of sites to individual leases.

South of the Kimberley, the number of sites per lease was restricted to a maximum of 10. This was to ensure that some very large leases, with high proportions of productive country did not dominate the site distribution. South of the Kimberley, a minimum of two sites were installed on leases except where the lease size was less than 500 km^2. In some cases, additional sites were required outside the regional stratification to ensure a minimum of 2 sites on leases which contained large proportions of unproductive land.

[6] John Beard published vegetation descriptions and maps for Western Australia at a range of scales, some published, some not. For a summary of this work see Beard 1990.

At the local scale, sites were installed so that a full range of vegetation states for each vegetation type in the region was encompassed within every 10 to 20 sites. The majority of sites were located within the most common state on the lease or group of adjacent leases.

Within the lease, sites were evenly distributed within each vegetation type, across the range of vegetation states, with priority given to locating sites within the largest grazed area of that vegetation type. Isolated or small areas of that type were avoided. Sites were located towards the centre of each area of a particular vegetation type rather than the margins. While it was not considered essential to sample every major land unit, efforts were made to sample all major land units within adjoining leases. Where patchiness was evident in the vegetation, the site was located to straddle the main variation if the patches were less than about 100 m across, or located in the most representative patch if patch diameter was greater than 100 m. Sites were not located in holding paddocks, laneways or other special use areas.

Sites were located at least 1.5 km from permanent water, except on chenopod vegetation types south of the Kimberley, where the stock water was saline (i.e. > 5,000 ppm total soluble salts). In these cases, the minimum distance was 1.0 km. Sites were located to consider ease of re-location and access, but so as not to be unnaturally affected by tracks and other infrastructure. In practice, this meant that sites were generally located between 150 m and 300 m from fence lines or tracks. Sites were not located on isolated examples of actively eroding land, or on dynamic areas such as river banks.

Species categories

Response categories

Individual species in the WARMS database were categorised as Decreaser, Increaser, Intermediate, or "not categorised". These reflect broad responses to grazing impacts under pastoralism.

Decreaser species are sensitive to grazing and decline in abundance under pastoral land use. Increaser species increase in response to grazing. In some situations, some Increaser species are termed woody weeds. Increaser species may decrease in abundance as a result of extremely heavy grazing and consequent decline in landscape functioning, such as massive scalding.

Intermediate species include both those defined as Intermediates and those defined as having no indicator value by Payne et al. (1998; p.132). Intermediate species may increase in abundance in response to low or moderate grazing but often decline as grazing pressure increases, partly because of landscape dysfunction and partly because they are grazed by livestock. Species that have no indicator value do not show a pattern of abundance related to grazing, unless extreme landscape dysfunction causes their decline.

Some species were not categorised, largely because their grazing response is unknown or disputed. These species tend to be less commonly found on WARMS sites.

For shrub species addressed in Attachment 3, 64 were categorised as Decreaser, 88 as Intermediate, 24 as Increaser and 45 were not categorised. While the not categorised species make up 20 per cent of the total species number they comprise less than 2 per cent of the number of individual plants recorded.

For perennial species addressed in Attachment 4, 39 were categorised as Decreaser, 64 as Intermediate, 15 as Increaser and 41 were not categorised. Of the perennial grasses, 15 were categorised as Decreaser, 12 as Intermediate and 5 as Increaser.

Turnover rate categories

Species dynamics can be more dependent on the longevity and recruitment rate of the species than on how the species responds to grazing. For example, during dry periods, long lived species tend not to have high mortality rates while short-lived species are likely to have high mortality rates.

The turnover rate (Eldridge et al. 1990) provides a means of categorising shrub species based on their life history attributes. It allows the two major components of demography; recruitment and mortality, to be combined into a single index. It is simply the average amount of change between two dates, as a ratio of the average population alive at those two dates, and is calculated as;

(((number of recruits) + (number of deaths))/2) / (((popn alive at Date 1) + (popn alive at Date 2))/2)

For this report, turnover rates were only calculated where there was at least one population on an individual site consisting of at least 20 individuals at either Date 1 or Date 2. The average turnover rate was calculated as the average of all populations of that species satisfying the 20 individual filtering criteria, weighted by the number of individuals in each category.

The thresholds used for the Turnover Rate Categories allocated to each species are;
0.50 < Very High Turnover Rate (TR_CAT 1) <= 999
0.35 < High Turnover Rate (TR_CAT 2) <= 0.50
0.20 < Moderate Turnover Rate (TR_CAT 3) <= 0.35
0.00 <= Low Turnover Rate (TR_CAT 4) <= 0.20

Seasonal conditions versus grazing

Data from range monitoring systems will never allow testing of *a priori* hypotheses about cause; replication and controls are not possible. Data analysis can only ever build a case for a particular interpretation of causal relationships (Hacker 1986). The case for (say) grazing will need to be based on an understanding of the mechanisms, rates and patterns of vegetation change in response to various perturbations (Watson 2003).

An ongoing issue for the design, analysis and interpretation of rangeland monitoring systems is the need to separate short term seasonal effects from longer term changes to resource condition. This is an important first step in building a case for causality. For example, assessing total standing herbage mass across large areas as demonstrated by the Aussie GRASS (Australian grassland and rangeland assessment by spatial simulation) project (Richards et al. 2001) demonstrates more about recent seasonal conditions than the effect of management. Results from grazing trials, such as that at Boolathana Station in the west Gascoyne clearly show that the effect of recent rainfall has a much greater influence on biomass than livestock stocking rate (Holm et al. 2003). By contrast, the demographies of perennial species are to some extent independent of recent seasonal conditions (Watson et al. 1997b).

Determining causality for change in rangelands will always be difficult. Major drivers of change include seasonal conditions, grazing pressure (both stocking rate per amount of feed and factors such as distance to water), fire and demographic inertia. For each of these drivers, there are many nuances, making it difficult to provide simple assessments of each driver. For example, seasonal conditions as summarised by total annual rainfall don't reflect the timing, frequency and intensity of rainfall, all of which contribute to its effect, as does the rainfall during preceding and successive periods of interest. Finally, the interactions between the major drivers serve to produce changes in rangelands. Many of these are poorly understood at the research level and therefore difficult to determine at the monitoring level.

For the vegetation indicators found on WARMS shrubland sites (principally change in density and change in canopy area of long lived shrubs) the principal mechanisms of change include seasonal conditions and grazing pressure. There are a number of ways that the relative impacts of season and grazing can be separated.

By only including relatively long lived species, WARMS tracks long term change in rangelands rather than short-term, seasonally driven change which is reflected in changes in herbage species. Because the changes on WARMS sites are less seasonally driven than biomass or cover of herbage there is an implicit dissociation from season. That is, negative changes are less likely to be due to unfavourable seasons alone.

Grazing is likely to be a causal factor where a decline is observed despite good seasons, sites decline while other sites in the region do not, or where palatable (Decreaser) species decline but other less palatable species (Increasers) do not.

The following sets out a conceptual model aimed at disentangling the impacts of seasonal conditions and grazing (Table 2.1). Should there be a decline in the indicator during favourable seasonal conditions, then that would suggest that some other factor, probably grazing, had an influence on the change. Conversely, should there be an improvement under unfavourable seasonal conditions then that would suggest that the grazing impact has been minimal. In general, if there has been an improvement then it is possible to say that the grazing impact did not over-ride the seasonal impact.

In Table 2.1, X and XX denote unfavourable situations in which decline occurred when seasonal conditions would suggest there should be improvement. By contrast, √ and √√ indicate favourable outcomes when seasonal conditions would indicate clear potential for decline. In the case of X and XX, the negative impact of grazing would be implicated. √ and √√ suggest that the impact of grazing was benign.

Table 2.1. Conceptual matrix to help judge attribution between seasonal conditions and grazing

Seasonal conditions	Decline	No Change	Improvement
Above average	XX	X	~
Average	X	~	√
Below average	~	√	√√

Seasonal quality categories (ACRIS groups)

The following approach was used to assign each site to a seasonal quality category – above average, average or below average (Table 2.1). The method produces a single seasonal category based on the five years preceding the year of assessment of each site. It also takes into account the influence of both annual rainfall and winter rainfall. The final result is that a seasonal category is given to each location (and ultimately each site) for each year. The procedure described below was used for shrubland sites. A slightly different procedure was used for grassland sites.

- Twelve locations with good long term rainfall records were selected in the Gascoyne – Murchison region.
- For each of the 12 locations, both the total annual rainfall (January to December) and the total winter rainfall (May to September) was ranked 1 to n (n = number years) and then allocated to one of three terciles.
- Scores of 1, 2 or 3 were given to each tercile (score 3 = lowest: score 1 = highest).
- A matrix was used to allocate a combined score of between 1 and 9, dependent on the combination of annual and winter tercile scores (see Table 2.2).
- The combined scores over five individual years were aggregated as a sum of that year and the previous four years, giving a total score for that year between 5 and 45.
- These total scores were then given a percent rank, i.e. their value as a percentage of the data set.
- Each of these percent ranks was then given a tercile score.
- For each individual WARMS site, the nearest of the 12 locations was identified and each site was categorised as above average, average or below average.

For grassland sites, the year total and summer (October to April) total (rather than winter total) was used to produce a combined score for each year, using the same approach as in Table 2.2. Combined scores were aggregated over three (rather than five) years.

Table 2.2. Matrix used to arrive at a combined score for each year based on annual and seasonal rainfall.

	Year tercile 1	Year tercile 2	Year tercile 3
Winter tercile 1	9	8	6*
Winter tercile 2	7	5	4*
Winter tercile 3	3	2	1

* unlikely to occur

The seasonal quality category for shrubland sites is given in Table 2.3 and for Grassland sites in Table 2.4.

Table 2.3. Shrubland sites - seasonal quality categories. Sites assessed in any one year use the category for the previous five years. That is, sites assessed in 2004 use the 99-03 group.

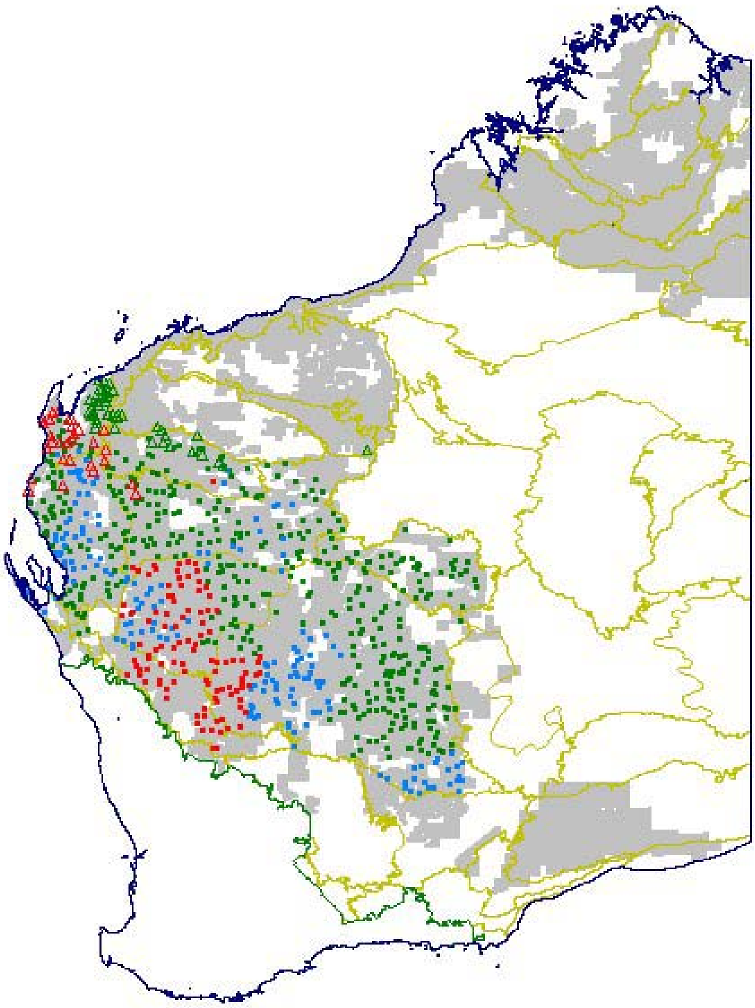
	94-98	95-99	96-00	97-01	98-02	99-03
Carnarvon	Above average	Above average	Above average	Average	Below average	Below average
Cue	Above average	Above average	Above average	Above average	Below average	Below average
Dairy Creek	Above average	Above average	Above average	Average	Below average	Below average
Kalgoorlie	Above average	Above average	Average	Average	Below average	Below average
Leonora	Average	Above average	Above average	Above average	Average	Average
Lyndon	Above average	Above average	Above average	Average	Below average	Below average
Meekatharra	Above average	Above average	Above average	Above average	Average	Below average
Mt Narryer	Average	Above average	Above average	Above average	Average	Below average
Sandstone	Above average	Above average	Above average	Above average	Average	Average
Three Rivers	Above average	Above average	Above average	Average	Average	Below average
Wiluna	Above average	Above average	Above average	Above average	Average	Below average
Yalgoo	Above average	Above average	Above average	Above average	Below average	Below average

Table 2.4. Grassland sites - seasonal quality categories. Sites assessed in any one year use the category for the previous three years. That is, sites assessed in 2004 use the 01-03 group.

	96-98	97-99	98-00	99-01	00-02	01-03
Carnarvon	Above average	Above average	Above average	Above average	Below average	Below average
Lyndon	Above average	Above average	Above average	Above average	Average	Below average
Three Rivers	Above average	Above average	Above average	Above average	Above average	Above average

The seasonal category for each site is shown in Figure 2.1.

Figure 2.1. Seasonal categories for WARMS sites used in the ACRIS pilot project report. Squares = shrubland sites; triangles = grassland sites. Above average = green; average = blue; below average = red. Greyed out areas are pastoral lands.

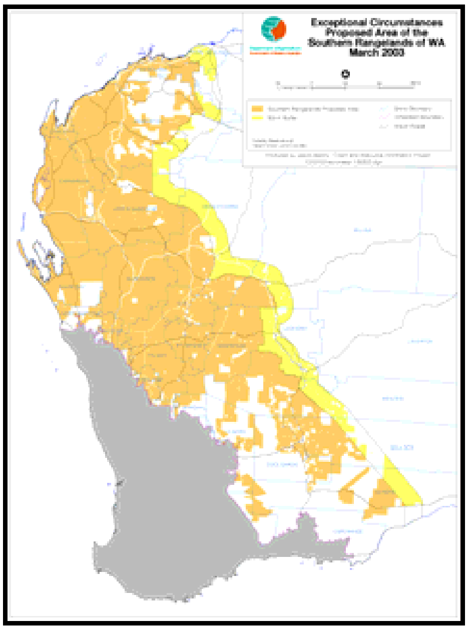


Seasonal condition categories (Exceptional Circumstances groups)

Prior to the application of the method described above to allocate seasonal quality categories, the following approach was used to allocate sites according to seasonal conditions in the Gascoyne – Murchison pilot region. The results for this categorisation are still reported in Attachment 3, although it is not part of the synthesised ACRIS work.

The Shrubland sites were divided into four groups based on the date of reassessment and whether or not the lease was within the area submitted to the Australian Government for Exceptional Circumstances (EC) (see Figure 2.2 and Figure 2.3). This declaration was made on the basis of successive dry seasons in 2001 and 2002. Many areas, particularly on the western side of the EC area also had a dry season in 2000. Generally speaking, the 2003 season was not good over much of the EC declared area and the 2004 season remained poor in the Murchison and Yalgoo areas. The groups shown in Figure 2.3 can be thought of as representing; sites not exposed to the dry period (i.e. Group 1) or sites sampled progressively into the dry period (Groups 2, 3 and 4). Note that while sites in Groups 2, 3 and 4 were reassessed during the dry period, they were all installed prior to July 1999, in years when rainfall was higher.

Figure 2.2. Area of the Southern Rangelands and Pilbara declared for Exceptional Circumstances (EC) assistance. The yellow strip is a 50 km buffer zone.



Group 2 sites experienced low rainfall for one to two years. Group 3 sites experienced low rainfall for two to three years. Group 4 experienced low rainfall for three to four years

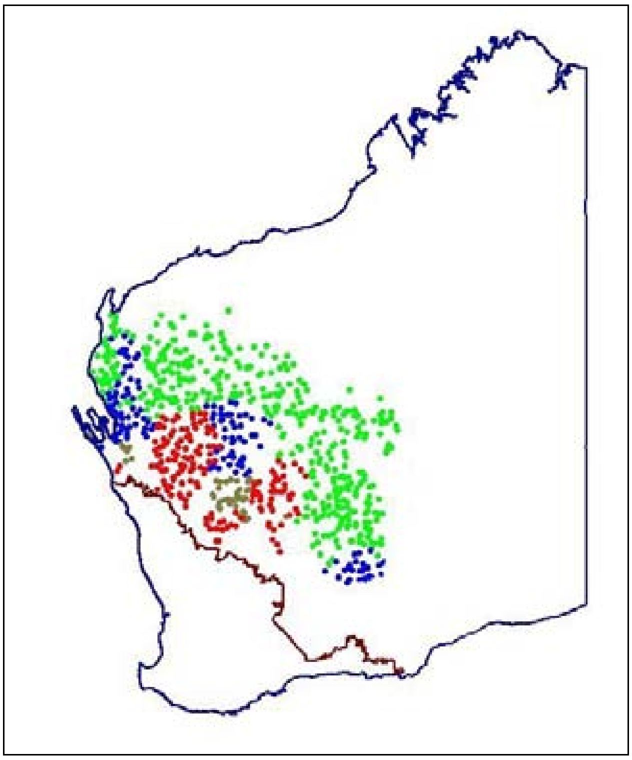
Figure 2.3. Locations of the 700 reassessed WARMS sites grouped into Exceptional Circumstances seasonal categories. The four groupings were;

Group 1, (green) 377 sites on leases that were either outside the EC area, or were within the EC area but reassessed before August 2001.

Group 2 (blue) 130 sites within the EC area and reassessed between August 2001 and August 2002.

Group 3 (brown) 45 sites within the EC area and reassessed between August 2002 and August 2003.

Group 4 (red) 148 sites within the EC area and reassessed between August 2003 and June 2004.



Attachment 3 – The Western Australian Rangeland Monitoring System (WARMS) shrubland sites – vegetation data

These results apply to WARMS shrubland sites only. Attachment 4 refers to WARMS grassland sites and Attachment 5 Landscape Function Analysis data. Background details for WARMS are found in Attachment 2.

Data set

- WARMS database as at 30/6/2004
- 700 shrubland sites reassessed from a total of 785 shrubland sites in the Australian Collaborative Rangeland Information System (ACRIS) region
- Average time between installation and reassessment was five years and 15 days but ranged from 3.8 years to 7.4 years.
- 52 per cent of sites had a reassessment interval between 4.5 and 5.5 years.
- Sites were reassessed on 240 stations, out of 263 stations that have WARMS shrubland sites within the region.
- Earliest date of first sampling (Date 1) was 2/12/1993 and the latest date of first sampling was 14/6/1999.
- Earliest date of second sampling (Date 2) was 25/8/1999 and the latest date of second sampling was 2/6/2004.
- A summary of population dynamics for all species recorded on the sites is provided as an appendix to this attachment.

Summary of change

Shrub density maintained or increased on 70 per cent of sites between installation and reassessment (Table 3.1). Sites sampled in drier conditions were more likely to have a reduced density of shrubs. For those sites sampled either outside the Exceptional Circumstances area (see Attachment 2) or before the dry period began, only 13 per cent showed decreased density and the average increase in density was 55 per cent. This progressively decreased as the sites were sampled further into the dry period. For Group 4 sites, the average decrease in density was 3 per cent. Overall, the average increase in density was 30 per cent.

A similar pattern emerged for changes in total canopy area (Table 3.1). The proportion of sites showing a decreased canopy area increased as the dry period progressed. Overall, only 18 per cent of sites showed a decreased canopy area, with an average increase in area of 50 per cent. However, during the latter stages of the dry period 64 per cent of sites decreased in canopy area with an average decrease of 5 per cent.

Table 3.1. Summary of changes found on 700 WARMS sites.

	Group 1 – Either not EC or EC but sampled before 2/8/01	Group 2 – EC and reassessed between 2/8/01 and 1/8/02	Group 3 - EC and reassessed between 2/8/02 and 1/8/03	Group 4 – EC and reassessed between 2/8/03 and 2/6/04	Overall – all dates combined
Percent of sites with decreased shrub density.	13%	35%	62%	58%	30%
Average change (%) in shrub density by site.	+55%	+10%	0%	-3%	+31%
Percent of sites with decreased total canopy area (i.e. cover).	3%	11%	24%	64%	18%
Average change (%) in total canopy area by site (i.e. cover).	+78%	+28%	+63%	-5%	+50%

Occurrence ratio

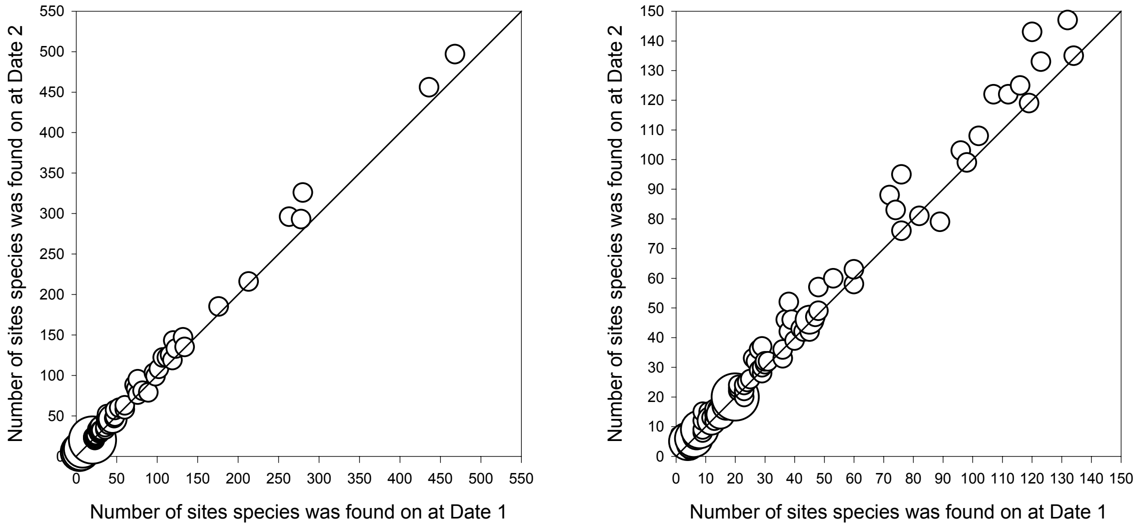
Occurrence Ratio is defined as the number of sites a species was found on at Date 2 divided by the number of sites the species was found on at Date 1. The metric provides an indication of change in local distribution. When greater than 1.0 it suggests the species distribution has expanded; when less than 1.0 it suggests the species distribution has contracted, at least within the representative areas sampled by WARMS.

Notes –

1. Applies to shrub and tree species recorded on WARMS Shrubland sites.
2. Results presented for all species found on at least five sites at either Date 1 or Date 2 (n=119, Figure 3.1) or.
3. As above (2) but also with a Response Category (Intermediate, Increaser, Decreaser) assigned to them (n=110, Figure 3.2) or.
4. As above (2) but also with a Turnover Rate Category assigned to them (n=87, Figure 3.3).

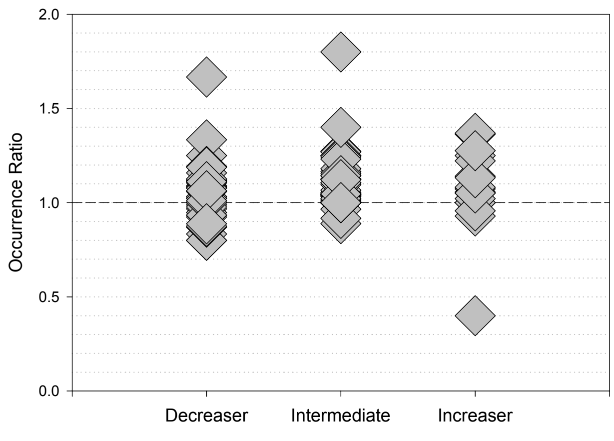
In general, native shrub and tree species were found on more sites at Date 2 than at Date 1. That is, their distribution or occurrence had increased between samplings. About 82 per cent of species had an occurrence ratio of at least 1.0. The average increase in occurrence was 9 per cent.

Figure 3.1. Occurrence ratio for all species with at least 5 populations at either Date 1 or Date 2. Each symbol represents an individual species. Where two or more species have the same coordinates a larger bubble size is used. The left pane shows all data, the right pane is an expanded view to show changes where the number of sites was 150 or less.



Two quite different species could be considered outliers. *Acacia farnesiana* (an Increaser) was found on 8 sites at Date 2, compared with zero sites at Date 1. *Santalum acuminatum* (quandong, a Decreaser) was found on 7 sites at Date 2 compared to only 2 sites at Date 1. All other species had Occurrence Ratios of less than two. *Solanum esuriale* (an Increaser) decreased in occurrence from 5 sites to 2. However, sample size for all three species was small (<29) and general conclusions about these species should be made with caution.

Figure 3.2. Occurrence ratio for species aggregated across sites and grouped by response category. Each symbol represents an individual species. A ratio of greater than one shows that the species was found on more sites at Date 2 than Date 1. The outliers *Acacia farnesiana* (divisor = zero) and *Santalum acuminatum* (ratio = 3.5) have not been plotted (see text).



If grazing was having a negative impact, the occurrence ratio for Decreaser species would be less than for Increaser species.

The majority of species in each response category had an occurrence ratio of at least 1.0. By response category, the statistics were Decreaser 70 per cent, Intermediate 94 per cent and Increaser 83 per cent of species.

The average ratios for each category were Decreaser 1.10, Intermediate 1.09 and Increaser 1.08.

Occurrence ratios for species with higher turnover rates were greater than for species with lower turnover rates (Figure 3.3). The average ratio for each category was Very High 1.54, High 1.17, Moderate 1.07 and Low 1.01. This pattern of decrease in rate from Very High to Low was expected given the general increase in occurrence across the full data set. Species with higher turnover rates are more likely to increase their occurrence because of their ability to colonise new areas rapidly. However, once established on a site demographic inertia will favour persistence on that site for longer lived species, while shorter lived species will have lower persistence. Following conditions conducive to a general decrease in occurrence it is more likely that higher turnover rate species would have an occurrence ratio considerably less than 1.0.

Figure 3.3. Occurrence ratio for species aggregated across sites and grouped by turnover rate category. Each symbol represents an individual species. A ratio of greater than one shows that the species was found on more sites at Date 2 than Date 1. The outliers *Acacia farnesiana* (divisor = zero) and *Santalum acuminatum* (ratio = 3.5) have not been plotted (see text).

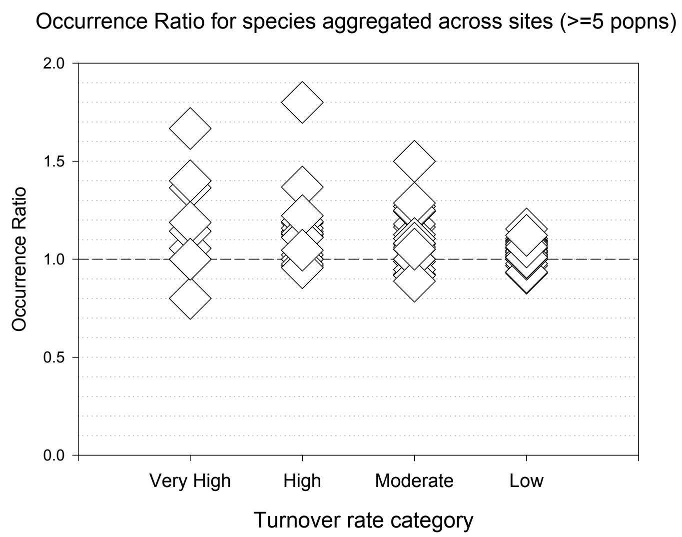


Table 3.2. Occurrence ratio of individual species – the first 15 listed had the largest occurrence ratios. The remainder all had ratios less than 1.0.

Species name	Response category	No. of populations at Date 1	No. of populations at Date 2	Occurrence Ratio	Number of individuals at Date 1	Number of individuals at Date 2
Acacia farnesiana	U		8	∞	0	29
Santalum acuminatum	D	2	7	3.50	2	7
Indigofera monophylla	I	5	9	1.80	46	70
Eremophila longifolia	D	9	15	1.67	13	41
Eremophila linearis		4	6	1.50	30	43
Senna glutinosa subsp. x luerssenii	I	5	7	1.40	20	46
Senna artemisioides subsp. x coriacea	U	38	52	1.37	153	262
Senna artemisioides	U	11	15	1.36	63	199
Eremophila oldfieldii	D	9	12	1.33	24	37
Psydrax suaveolens		28	36	1.29	85	122
Solanum orbiculatum	U	29	37	1.28	60	74
Acacia citrinoviridis	I	11	14	1.27	16	26
Acacia sclerosperma	I	26	33	1.27	107	198
Alectryon oleifolius	D	4	5	1.25	5	6
Hakea preissii	U	76	95	1.25	249	404
Above; largest 15 Occurrence Ratios. Below; all species with occurrence ratio less than 1.0						
Atriplex bunburyana	D	82	81	0.99	2464	2774
Maireana glomerifolia	D	43	42	0.98	474	465
Rhagodia drummondii		40	39	0.97	142	177
Atriplex vesicaria	D	60	58	0.97	2041	2161
Eremophila granitica	I	29	28	0.97	269	414
Senna artemisioides subsp. x artemisioides	U	23	22	0.96	56	82
Eremophila aff. Compacta	D	19	18	0.95	365	447
Maireana platycarpa	D	45	42	0.93	1031	1000
Maireana atkinsiana	D	15	14	0.93	76	80
Eremophila spathulata		15	14	0.93	110	138
Eremophila punicea	U	14	13	0.93	270	307
Atriplex amnicola	D	13	12	0.92	514	407
Halosarcia species	I	36	33	0.92	571	618
Exocarpos aphyllus	I	9	8	0.89	10	15
Sida calyxhymenia	D	89	79	0.89	406	384
Scaevola tomentosa	D	8	7	0.88	19	17
Maireana thesioides	D	23	20	0.87	58	49
Atriplex nummularia	D	6	5	0.83	22	21
Eremophila laanii	D	5	4	0.80	38	22
Maireana amoena	D	5	4	0.80	22	25
Solanum esuriale	U	5	2	0.40	13	3

Species richness

Site species richness is a measure of how many species are found on each site at each assessment.

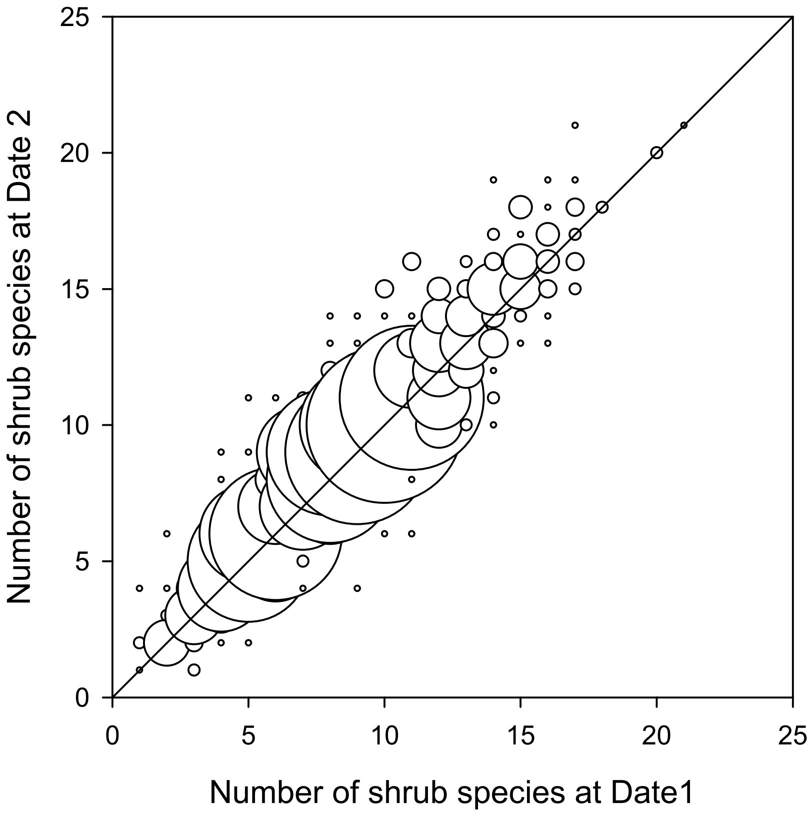
It is calculated as;

(number of species found on the site at Date 2) / (number of species found on the site at Date 1)

Given that all species are native, an increase in species richness represents an improvement, except in cases where it may represent the initial foothold of a woody weed invasion.

Of the 700 shrubland sites reassessed, 561 (80 per cent) retained or increased species richness when comparing Date 1 to Date 2 (Figure 3.4.4).

Figure 3.4. Species richness for each site –number of species found on the site at Date 2 compared to the number of species found on the site at Date 1 (n=700).



When only Decreaser species were considered, 83 per cent retained or increased species richness between Date 1 and Date 2.

Population growth rate (i.e. change in density)

Population growth rate (PGR) is defined as the number of individuals at Date 2 divided by the number of individuals at Date 1. It can be thought of as equivalent to density, since the transect areas remained constant between the two dates.

In general a PGR of greater than 1.0 (i.e. increased density) is considered desirable. However, an increase of Increaser species may not be desirable if the objective is that of pastoral productivity.

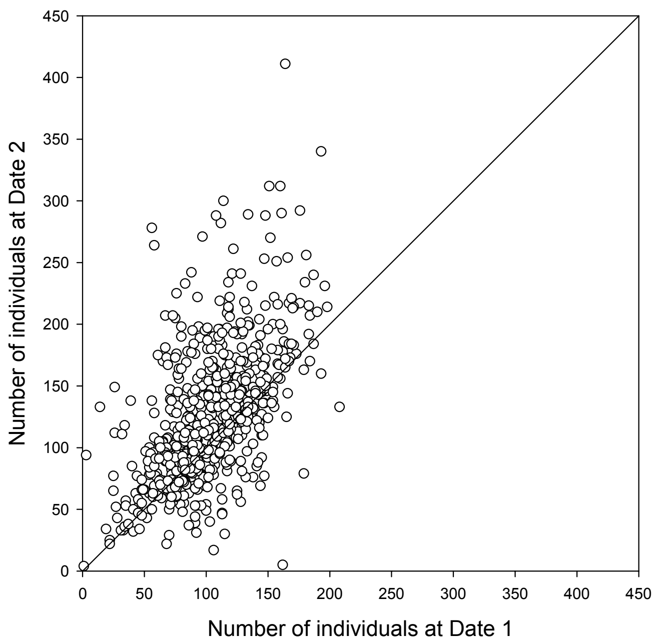
If grazing management was benign, the expectation is that the PGR of Decreaser, Intermediate and Increaser species would be similar.

Notes –

1. Applies to shrub and tree species recorded on WARMS Shrubland sites.
2. Raw data used, not standardised for time between assessment.
3. Results presented for all individuals found on each site irrespective of population size (n=700, Figure 3.5)

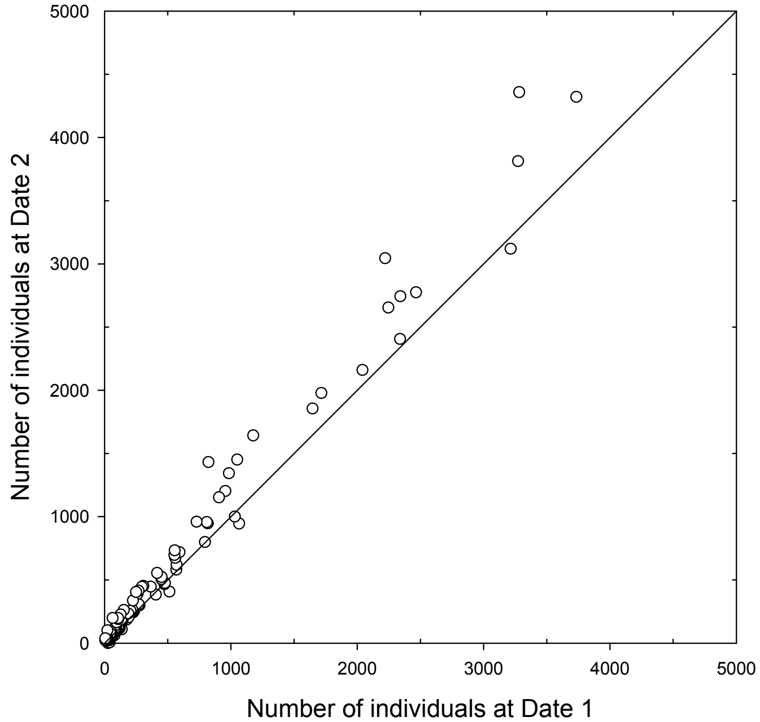
Most sites (70 per cent) had a PGR of at least 1.0, i.e. there were at least as many individuals on the site at Date 2 as at Date 1 (Figure 3.5). Only 16 per cent of sites had a PGR of less than 0.90. The average population growth rate for all sites was 1.31.

Figure 3.5. Population growth rate for each site – number of individuals on each site at Date 2 compared to number of individuals on each site at Date1 (n=700).



The majority of species (87 per cent) had a PGR of at least 1.0. Only 7 per cent had a PGR of less than 0.9 (Figure 3.6). The average PGR for this set of species was 1.35. These results apply to all species with at least 20 individuals at either Date 1 or Date 2 and at least 1 individual at Date 1.

Figure 3.6. Population growth rate for each species in which there was at least 20 individuals at either Date 1 or Date 2 and the initial number was at least 1. *Ptilotus obovatus* has not been included on this graph because the number of individuals was way in excess of the other species. The initial number of *Ptilotus obovatus* was 14,944 and the final number was 19,145 (PGR=1.28).



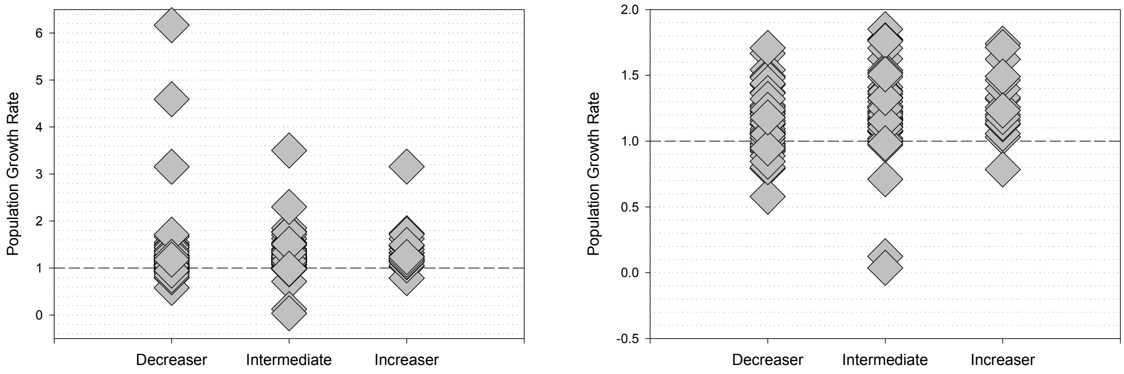
There was little difference in the average PGR of the three response categories (Decreaser 1.37, Intermediate 1.27 and Increaser 1.39) although there may be a trend in the proportion of species within each response group with a PGR of at least 1.0 (Decreaser 77 per cent, Intermediate 89 per cent and Increaser 95 per cent) (Figure 3.7).

Two points to note

1) Figure 3.7 does not contain *Acacia farnesiana*, numbers of which increased from 0 to 29 (because of division by zero issue).

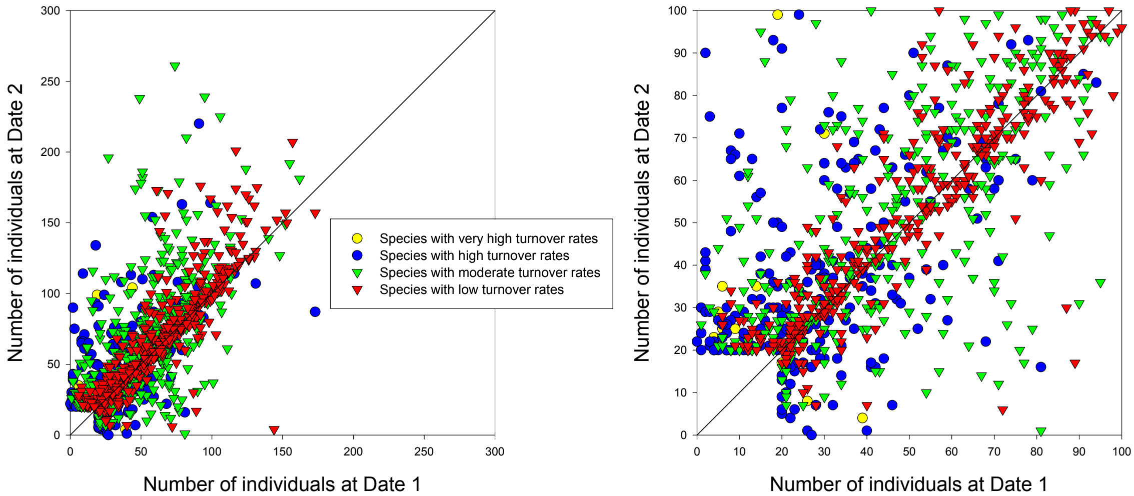
2) A total of eight other species could be considered outliers (2 < 0.5 and 6 > 2.0). However, the total number of individuals was low for six of these species (< 42). The other two species *Senna artemisioides* and *Muehlenbeckia florulenta* had a PGR of 3.16 and 4.59 respectively with total number of individuals of 207 and 102.

Figure 3.7. Population growth rate for species aggregated across sites and grouped by response category, where either the initial or final number of individuals was at least 20 and the initial number was at least one. The left pane shows all species, the right pane has been limited to all species with a PGR of less than 2.0 in order to show the bulk of species more clearly.



Some of the site changes can be explained by the turnover rate categories on the sites Figure 3.8. Higher turnover rates generally signify faster dynamics.

Figure 3.8. Population growth rates for aggregations of turnover rate categories by site.



The 20 species with the highest population growth rate as well as all species in which density declined are shown in Table 3.3.

Table 3.3. Population growth rate of individual species (all those <1.0 and highest 20 of the others).

Species	Response category	No. popns at Date 1	No. popns at Date 2	Initial no.	No. deaths	No. recruits	Final no.	Popn Growth Rate
Brachyscome latisquamea	D	1	3	6	0	31	37	6.17
Olearia pimeleoides		2	3	6	0	25	31	5.17
Muehlenbeckia florulenta	D	3	2	22	2	81	101	4.59
Dodonaea lobulata	I	4	5	6	1	16	21	3.50
Senna artemisioides	U	11	15	63	8	144	199	3.16
Eremophila longifolia	D	9	15	13	1	29	41	3.15
Senna glutinosa subsp. x luerssenii	I	5	7	20	1	27	46	2.30
Acacia sclerosperma	I	26	33	107	6	97	198	1.85
Acacia anastema	I	7	7	44	1	35	78	1.77
Eremophila mackinlayi	I	2	2	128	34	132	226	1.77
Eremophila homoplastica		3	3	51	4	43	90	1.76
Pimelea microcephala	I	21	24	46	15	50	81	1.76
Eremophila glandulifera		2	2	108	10	91	189	1.75
Acacia victoriae	U	107	122	823	127	736	1432	1.74
Senna artemisioides subsp. x coriacea	U	38	52	153	24	133	262	1.71
Senna glutinosa ssp. chatelainiana	D	48	57	96	12	80	164	1.71
Acacia cuthbertsonii	I	3	3	17	2	14	29	1.71
Eremophila malacoides	D	8	9	51	0	34	85	1.67
Acacia citrinoviridis	I	11	14	16	0	10	26	1.63
Hakea preissii	U	76	95	249	11	166	404	1.62
Above; largest 20 Population Growth Rates. Below; all species with Population Growth Rates less than 1.0								
Stylobasium spathulatum	I	20	20	119	33	31	117	0.98
Maireana glomerifolia	D	43	42	474	34	25	465	0.98
Maireana pyramidata	I	134	135	3213	316	222	3119	0.97
Maireana platycarpa	D	45	42	1031	152	121	1000	0.97
Atriplex nummularia	D	6	5	22	1	0	21	0.95
Eremophila gibsonii		1	1	22	3	2	21	0.95
Sida calyxhymenia	D	89	79	406	115	93	384	0.95
Lepidium platypetalum	D	1	1	46	15	12	43	0.93
Eremophila strongylophylla	D	1	1	38	5	2	35	0.92
Maireana planifolia	D	119	119	1065	435	315	945	0.89
Maireana thesioides	D	23	20	58	21	12	49	0.84
Gunniopsis quadrifida	D	20	20	136	51	24	109	0.80
Atriplex amnicola	D	13	12	514	182	75	407	0.79
Eremophila aff. Gilesii	U	1	2	79	35	18	62	0.78
Eremophila lachnocalyx	I	3	4	38	16	5	27	0.71
Eremophila laanii	D	5	4	38	22	6	22	0.58
Hemigenia tysonii	I	2	2	40	35	0	5	0.13
Pittosporum phylliraeoides	I	2	1	27	27	1	1	0.04

There were marked differences between response categories in terms of the change in density (Table 3.4). When all species were considered together, the proportion of sites in which density declined increased as the dry period progressed. This was particularly the case for Decreaser species. Only 15 per cent of those sites in Group 1 showed a decreased density between assessments, but this steadily increased to 63 per cent for Group 4 sites, i.e. further into the dry period. This was in contrast to Increaser species. Intermediate species showed a response in-between these. The fact that the response by Decreaser species was different to that by Increaser species suggests that that grazing had an impact on the decline in density over and above that due to the dry conditions alone.

Table 3.4. The percent of sites in which shrub density decreased between reassessment dates, by EC Group and response category.

Percent of sites with decreased shrub density	Group 1 – Either not EC or EC but sampled before 2/8/01	Group 2 – EC and reassessed between 2/8/01 and 1/8/02	Group 3 - EC and reassessed between 2/8/02 and 1/8/03	Group 4 – EC and reassessed between 2/8/03 and 2/6/04	Overall – all dates combined
ALL SPECIES	13%	35%	62%	58%	30%
DECREASER SPECIES	15%	37%	58%	63%	32%
INTERMEDIATE SPECIES	17%	26%	38%	44%	26%
INCREASER SPECIES	12%	17%	15%	18%	14%

Consistent declines in population growth rates of Decreaser species as the dry period progressed were evident for all species in which there were at least 20 individuals in each of the four EC group categories (Table 3.5).

Table 3.5. Population growth rate (Numbers at Date 2 / Number at Date 1) for all species with at least 20 individuals at either Date 1 or Date 2 in each of the four Exceptional Circumstances (EC) Groups

Response category	Species	EC 1	EC 2	EC 3	EC 4
Intermediate	*Acacia aneura*	1.18	1.14	1.05	1.23
Intermediate	*Acacia linophylla*	1.34	1.28	0.90	1.15
Intermediate	*Acacia ramulosa*	1.14	1.12	1.03	1.18
Intermediate	*Acacia tetragonophylla*	1.57	1.23	0.99	1.27
Decreaser	*Atriplex bunburyana*	1.30	0.94	0.99	0.68
Decreaser	*Atriplex vesicaria*	1.11	1.04	0.70	1.00
Intermediate	*Eremophila forrestii*	1.21	1.17	1.11	1.03
Increaser	*Eremophila fraseri*	1.29	1.06	0.91	1.15
Intermediate	*Eremophila georgei*	1.22	1.08	1.12	1.05
Decreaser	*Frankenia species*	1.31	0.90	1.01	0.98
Decreaser	*Maireana convexa*	1.85	0.72	0.60	0.56
Decreaser	*Maireana georgei*	1.82	0.99	1.09	1.11
Intermediate	*Maireana pyramidata*	0.96	1.01	0.96	0.99
Decreaser	*Maireana villosa*	1.60	0.85	1.08	0.51
Decreaser	*Ptilotus obovatus*	1.67	1.17	0.95	0.87
Decreaser	*Ptilotus schwartzii*	1.20	1.07	0.87	0.95
Decreaser	*Rhagodia eremaea*	1.59	1.09	0.77	1.04
Intermediate	*Solanum lasiophyllum*	1.63	1.19	1.39	0.67
Intermediate	*Spartothamnella teucriiflora*	1.77	1.40	1.00	1.13

Using a definition of decline as a decrease in density of more than five per cent and an improvement as an increase in density of more than five per cent, Table 3.6 and Table 3.7 provide a summary for the EC Group method and the ACRIS method.

Table 3.6. Population growth rates (i.e. change in density) Percentage of sites in each seasonal category (EC Group method). Exceptional Circumstances (EC) groups range from very favourable seasonal conditions (EC Group 1) to very unfavourable seasonal conditions (EC Group 4).

EC Group	Species included	Decline PGR < 0.95 (density < 95%)	No change 0.95>= PGR < 1.05 (density between 95% and 105%)	Improvement PGR >= 1.05 (density >=105%)	Number of sites
1	All	10	9	81	377
	Decreaser	12	12	77	363
	Intermediate	16	15	69	355
	Increaser	11	18	71	249
2	All	26	25	49	130
	Decreaser	32	22	46	126
	Intermediate	20	24	57	123
	Increaser	14	32	55	96
3	All	40	36	24	45
	Decreaser	49	22	29	45
	Intermediate	23	50	27	44
	Increaser	15	42	42	26
4	All	46	22	32	148
	Decreaser	55	18	27	147
	Intermediate	36	31	32	140
	Increaser	18	34	48	85

Table 3.7. Population growth rate (i.e. change in density). Percentage of sites in each seasonal category (ACRIS method) showing decline, no change or improvement following above average, average or below average seasonal conditions during the five years prior to the year in which the site was recorded.

Seasonal Quality	Species included	Decline PGR < 0.95 (density < 95%)	No change 0.95>= PGR < 1.05 (density between 95% and 105%)	Improvement PGR >= 1.05 (density >=105%)	Number of sites
Above average	All	12	12	77	428
	Decreaser	15	13	72	412
	Intermediate	17	17	67	403
	Increaser	11	21	68	284
Average	All	28	27	45	166
	Decreaser	37	20	43	163
	Intermediate	20	34	46	158
	Increaser	17	30	53	99
Below average	All	58	21	22	106
	Decreaser	60	20	20	106
	Intermediate	42	30	29	101
	Increaser	18	34	48	73

Recruitment

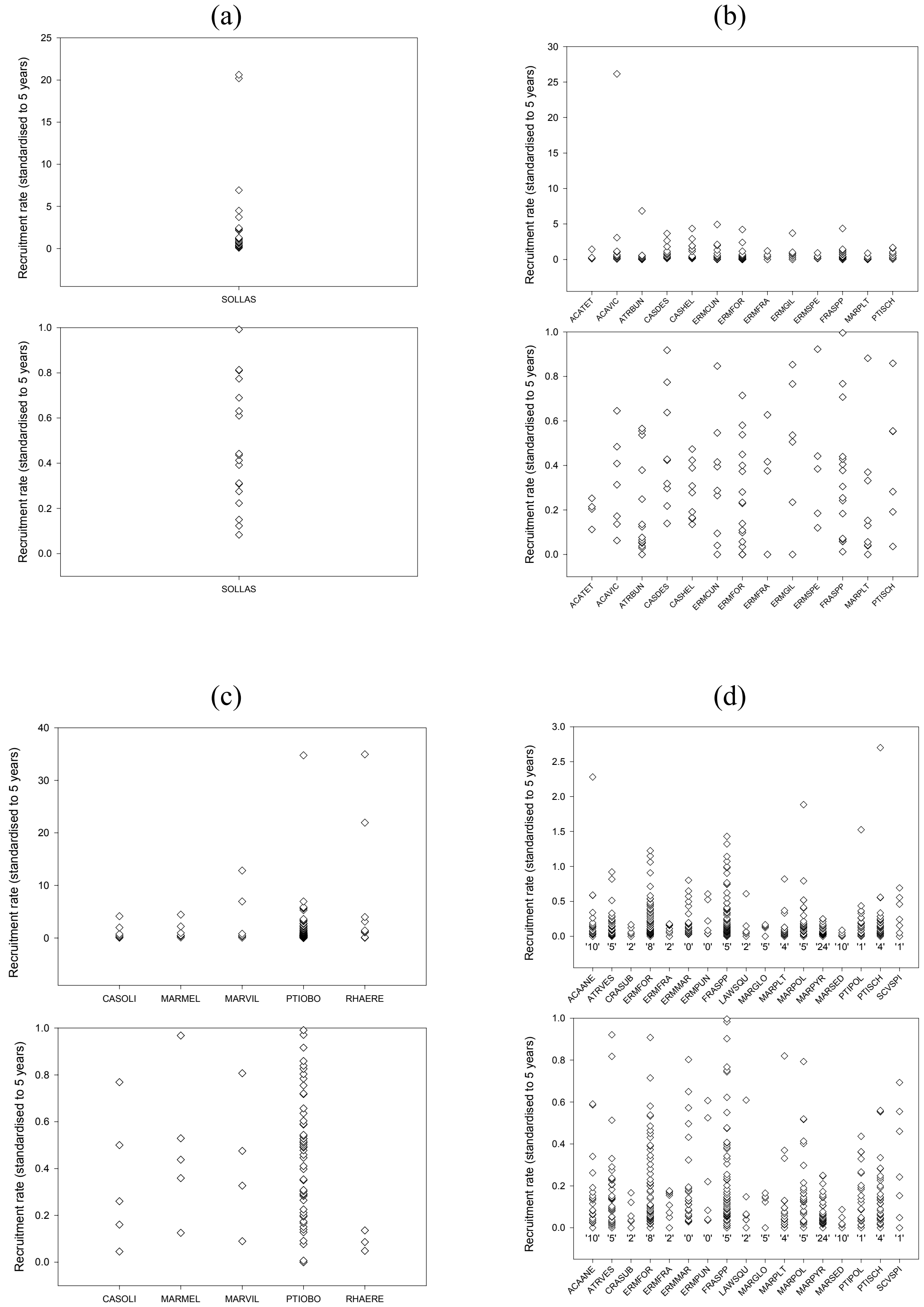
At least some recruitment was observed on 696 of the 700 sites reassessed.

Of the 221 species found on the 700 reassessed sites, at least one recruit was recorded for 179 species (81 per cent). This result was regardless of population size (i.e. zero recruitment would be expected for some species because of very small initial population size).

When only those species that had a population size (pooled across all sites) of at least 20 individuals at either the first date or second date were considered, 137 of 139 (99 per cent) showed at least some recruitment. Of the Decreaser species, recruitment was found for 47 of 48.

Intrinsic turnover rates of each species have a large influence on recruitment rates. High turnover rate species tend to have higher recruitment rates than low turnover rate species.

Figure 3.9. Distribution of recruitment rate for species in different Turnover Rate Categories (a) very high, (b) high, (c) moderate and (d) low - for all species with five or more populations having at least 20 individuals at either Date 1 or Date2. Each symbol represents the population of the nominated species on a single site. The data have been standardised to five years. The top pane shows all data, the bottom pane is an expanded view to better show recruitment rates between zero and one. Species codes as in Appendix 1.



Comparisons of recruitment rates by Decreaser, Increaser and Intermediate are difficult because recruitment is dependent more on whether species are shorter-lived or longer-lived (i.e. turnover rate) rather than their response to grazing. Shorter-lived species tend to have much higher recruitment rates than longer-lived species. Summaries by grazing response category are inevitably skewed by the longevity of the species used.

However, for sites reassessed in the late dry period (EC Group 4) all Decreaser species having at least 20 individuals on at least five sites showed some recruitment. Recruitment rates were relatively low for *Atriplex vesicaria* and *Maireana planifolia* (Table 3.8). For long-lived species such as *Ptilotus schwartzii*, recruitment rates of 9 per cent are easily sufficient to maintain populations, given expected higher recruitment during good seasonal conditions. Recruitment rates were unexpectedly high for *Ptilotus obovatus* bush and *Maireana georgei* bluebush given the dry seasonal conditions.

Recruits found on sites that were assessed late in the dry period (EC Group 4) almost certainly germinated during earlier wetter periods. However, the fact that they survived so far into the dry period is encouraging and suggests that grazing pressure was not sufficient to remove them from the populations.

Table 3.8. Recruitment rates for all species having at least five populations consisting of at least 20 individuals in each population (initial or final) in at least three of the Exceptional Circumstances Groups. Recruitment rate is expressed as the number of recruits recorded during reassessment as a percentage of the number of plants at installation.

Species	Response category	EC1	EC2	EC3	EC4
Atriplex bunburyana	Decreaser	70%	23%	21%	-
Atriplex vesicaria	Decreaser	38%	15%	-	7%
Eremophila forrestii	Intermediate	47%	23%	-	16%
Frankenia species	Decreaser	68%	10%	-	14%
Maireana georgei	Decreaser	532%	-	51%	69%
Maireana planifolia	Decreaser	96%	40%		3%
Maireana pyramidata	Intermediate	20%	-	1%	17%
Ptilotus obovatus	Decreaser	174%	37%	29%	22%
Ptilotus schwartzii	Decreaser	68%	39%	7%	9%
Solanum lasiophyllum	Intermediate	293%	66%	-	177%

Canopy area – an estimate of cover

Canopy area is defined as the area of a circle defined by the estimated width of each plant, i.e. (pi * ((width/2)^2)). This is not a direct measure of cover, but can be considered to increase or decrease at the same rate and in the same direction as cover.

The canopy size of plants is influenced more than population dynamics by seasonal conditions. That is, plants tend to get smaller during dry periods and larger during wetter periods. This is particularly the case for smaller, shorter lived species such as *Ptilotus obovatus*. The canopy sizes of many large species, such as mulga, remain relatively stable even during prolonged dry periods. Because of their large size, they tend to dominate the data set. For this reason, the data were filtered for some results to exclude those individuals that were taller than 1.5 m.

Another factor that drives the understanding of canopy size is the dominance of the data set by *Ptilotus obovatus*. This species alone represents about 23 per cent of all plant records, so changes to this species disproportionally affect the entire data set. The characteristics of *Ptilotus obovatus* are that it is a Decreaser species that is very plastic in canopy size, reducing rapidly under grazing and dry conditions, only to increase size rapidly when conditions allow.

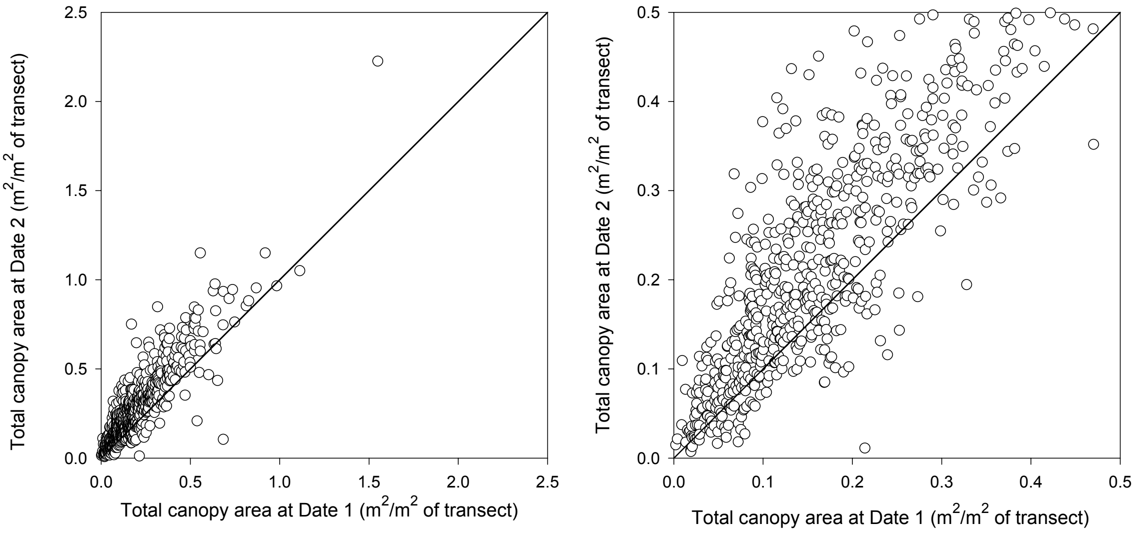
Notes –

1. The total canopy area is the sum of the individual canopy areas and therefore does not consider overlap of canopy within or between storeys.
2. The assumptions that all canopies are circular in plan view and that all canopies have a projected cover of 1.0 are clearly simplified.

Canopy area increased on 82 per cent of sites (Figure 3.10). The average change in canopy area per site was 50 per cent. These changes were the result of both a large increase in the size of plants common to both dates and by an increase in the density of plants, i.e. by population growth rates being greater than 1.0.

When only those individuals shorter than 1.5 m were included, cover increased on 79 per cent of sites, with the average increase per site being 71 per cent. Nearly all species (64 of 65) showed an average increase in canopy.

Figure 3.10. Change in total canopy area of each site between Date 1 and Date 2. Each symbol represents a single site. Total canopy area increased between Date 1 and Date 2 for all sites above and to the left of the diagonal line. The left pane shows all data, the right pane is an expanded view to better show changes where the total canopy area at Date 1 was less than 0.5. Raw data used, not standardised to five years.



For 95 per cent of species the canopy size increased between Date 1 and Date 2 (where there was at least 20 individuals at Date 1 or Date 2). The average increase was 1.63 for Decreaser species (n=49), 1.49 for Intermediate species (n=55) and 1.48 for Increaser species (n=19).

Change in canopy size is related to response category, particularly when conditions are dry, since grazing has a direct impact on canopy size. The increasingly dry conditions in the pilot project region had a large impact on canopy size, particularly amongst the Decreaser species (Table 3.9). This suggests that the impact of grazing was additional to the impact of seasonal conditions.

Table 3.9. The percent of sites in which total canopy area of all plants less than 1.5 m tall decreased between reassessment dates.

Percent of sites with decreased total canopy area (i.e. cover).	Group 1 – Either not EC or EC but sampled before 2/8/01	Group 2 – EC and resampled between 2/8/01 and 1/8/02	Group 3 - EC and resampled between 2/8/02 and 1/8/03	Group 4 – EC and resampled between 2/8/03 and 2/6/04	Overall – all dates combined
ALL SPECIES	3%	15%	47%	66%	21%
DECREASER SPECIES	7%	25%	73%	75%	29%
INTERMEDIATE SPECIES	6%	15%	27%	41%	16%
INCREASER SPECIES	7%	10%	19%	24%	12%

The change in cover for individual species that had sufficient numbers sampled in each of the Exceptional Circumstances (EC) Groups is shown in Table 3.10.

Table 3.10. Cover ratio (cover at Date 2 / cover at Date 1) for all species with at least 20 individuals at either Date 1 or Date 2 in each of the four Exceptional Circumstances Groups.

Response category	Species	EC 1	EC 2	EC 3	EC 4
Intermediate	*Acacia aneura*	1.25	1.06	3.55	0.98
Intermediate	*Acacia linophylla*	1.83	1.08	1.11	1.14
Intermediate	*Acacia ramulosa*	1.40	1.10	1.97	0.89
Intermediate	*Acacia tetragonophylla*	1.70	1.36	1.41	1.06
Decreaser	*Atriplex bunburyana*	1.58	1.75	0.99	0.54
Decreaser	*Atriplex vesicaria*	1.42	1.24	0.94	0.96
Intermediate	*Eremophila forrestii*	1.70	1.35	1.42	1.11
Increaser	*Eremophila fraseri*	1.32	1.23	1.21	1.17
Intermediate	*Eremophila georgei*	1.53	3.84	1.83	1.45
Decreaser	*Frankenia species*	1.68	0.99	0.97	0.97
Decreaser	*Maireana convexa*	2.94	1.57	0.45	0.53
Decreaser	*Maireana georgei*	3.71	0.79	0.91	1.02
Intermediate	*Maireana pyramidata*	1.54	1.26	0.93	1.04
Decreaser	*Maireana villosa*	2.90	0.73	0.72	0.31
Decreaser	*Ptilotus obovatus*	2.70	1.23	0.85	0.37
Decreaser	*Ptilotus schwartzii*	1.50	0.69	0.36	0.44
Decreaser	*Rhagodia eremaea*	1.57	1.34	1.22	0.75
Intermediate	*Solanum lasiophyllum*	4.33	1.90	1.80	0.21
Intermediate	*Spartothamnella teucriiflora*	2.72	2.31	1.32	1.13

Using a definition of decline as a decrease in canopy area of more than 10 per cent and an improvement as an increase in canopy area of more than 10 per cent, Table 3.11 and Table 3.12 provide a summary for the Exceptional Circumstances Group method and the ACRIS method.

Table 3.11. Percent of sites showing decline, no change or improvement in cover, after excluding individuals taller than 1.5 m, by seasonal quality and response group (Exceptional Circumstances Group method).

EC Group	Species included	Decline Total canopy area < 0.90	No change 0.90>= Total canopy area <1.10	Improvement Total canopy area >= 1.10	Number of sites
1	All	2	3	95	377
	Decreaser	5	5	90	370
	Intermediate	5	4	91	363
	Increaser	5	5	91	280
2	All	6	15	78	130
	Decreaser	19	11	79	128
	Intermediate	11	7	83	122
	Increaser	9	3	88	102
3	All	31	24	44	45
	Decreaser	64	11	24	45
	Intermediate	13	24	62	45
	Increaser	15	7	78	27
4	All	52	23	25	148
	Decreaser	71	10	19	148
	Intermediate	31	21	48	140
	Increaser	15	16	70	89

Table 3.12. Percent of sites showing decline, no change or improvement in cover, after excluding individuals taller than 1.5 m, by seasonal quality and response group (ACRIS method).

	Species included	Decline Total canopy area < 0.90	No change 0.90>= Total canopy area <1.10	Improvement Total canopy area >=1.10	Number of sites
Above Average	All	3	4	93	428
	Decreaser	7	5	88	412
	Intermediate	6	4	90	402
	Increaser	5	5	89	280
Average	All	20	25	54	166
	Decreaser	40	14	46	163
	Intermediate	18	17	66	157
	Increaser	14	7	79	96
Below Average	All	58	15	26	106
	Decreaser	77	7	16	106
	Intermediate	29	19	52	99
	Increaser	15	14	70	71

A note of caution

In the last few years, the general conclusion from the vegetation data found on WARMS shrubland sites is that there has been substantial improvement. This conclusion principally comes from some earlier work (Watson and Thomas 2003) completed following a period of much above average rainfall. The current work, despite the dry conditions since early 2000, reinforces this view. However, this conclusion needs to be considered in light of the suggestion by Pringle and Tinley (2003) that significant catchment level dysfunction is being overlooked. While their results considered Murchison landscapes, their conclusion applies equally to the entire ACRIS pilot project region.

Pringle and Tinley considered that many areas have suffered a lowering of base levels, leading to a more marked and rapid loss of rainfall from the landscape. This has in turn led to gully systems cutting back onto floodplains, large areas of sheetflood plains becoming increasingly perched and generally poorer water relations in many areas. They suggest that the results from WARMS do not reflect this catchment level dysfunction.

Pringle et al. (submitted) have proposed a model to show how these two apparently contradictory conclusions can be reconciled. They suggest that WARMS sites are located on large, uniform and relatively intact parts of the landscape, rather than at the dynamic edges where Pringle and Tinley (2003) have noted signs of dysfunction. This deliberate bias is part of the WARMS site selection and location criteria (see Watson *et al.* 2001) which aims to report on areas representative of the bulk of the landscape, but it may mean that the signs of catchment dysfunction noted by Pringle and Tinley (2003) will take some time before they are evident on WARMS sites.

Species with at least one popn having at least 20 individuals at either date 1 or date 2	Species name	Common name	Species Code	Response category	No_popn _D1	No_popn _D2	Initial	Number of plants that died	Number of recruits	Final	Occurrence ratio	Rec Rate	Survivorship	Turnover Rate	Population Growth Rate	Species with at least one popn having at least 20 individuals at either date 1 or date 2
	Acacia acuminata	Jam	ACAACU	Intermediate	6	6	15	0	0	15	1.00	0.00	1.00	0.00	1.00	
ACAANA	*Acacia anastema*	Sand dune gidgee	ACAANA	Intermediate	7	7	44	1	35	78	1.00	0.80	0.98	0.30	1.77	ACAANA
	Acacia ancistrocarpa	Fitzroy wattle	ACAANC	Intermediate	2	2	5	1	0	4	1.00	0.00	0.80	0.11	0.80	
ACAANE	*Acacia aneura*	Mulga	ACAANE	Intermediate	278	293	2340	85	489	2744	1.05	0.21	0.96	0.11	1.17	ACAANE
	Acacia bivenosa	Coastal wattle	ACABIV	Intermediate	1	2	2	1	1	2	2.00	0.50	0.50	0.50	1.00	
	Acacia brachystachya	Turpentine mulga	ACABRA	Intermediate	2	2	4	0	4	8	1.00	1.00	1.00	0.33	2.00	
	Acacia burkittii	Burkitt's wattle, pinbush wattle	ACABUR	Intermediate	14	16	42	4	19	57	1.14	0.45	0.90	0.23	1.36	
	Acacia citrinoviridis	Golden wattle	ACACIT	Intermediate	11	14	16	0	10	26	1.27	0.63	1.00	0.24	1.63	
ACACOO	*Acacia coolgardiensis*	Sugar brother	ACACOO	Intermediate	1	1	15	0	5	20	1.00	0.33	1.00	0.14	1.33	ACACOO
	Acacia coriacea	Weeping acacia	ACACOR	Intermediate	2	2	2	0	0	2	1.00	0.00	1.00	0.00	1.00	
ACACRA	*Acacia craspedocarpa*	Hop mulga	ACACRA	Intermediate	25	26	111	3	11	119	1.04	0.10	0.97	0.06	1.07	ACACRA
ACACUS	*Acacia cuspidifolia*	Bohemia, wait-a-while	ACACUS	Intermediate	30	31	225	22	38	241	1.03	0.17	0.90	0.13	1.07	ACACUS
	Acacia cuthbertsonii	Snakewood type	ACACUT	Intermediate	3	3	17	2	14	29	1.00	0.82	0.88	0.35	1.71	
	Acacia demisa	Murchison willow	ACADEM		1	1	1	0	0	1	1.00	0.00	1.00	0.00	1.00	
	Acacia distans	Black mulga, gascoyne jam	ACADIS	Intermediate	2	2	5	0	0	5	1.00	0.00	1.00	0.00	1.00	
	Acacia drepanophylla	Hamelin wattle(cb endemic)	ACADRE	Intermediate	1	1	6	0	0	6	1.00	0.00	1.00	0.00	1.00	
	Acacia eremaea	Snakewood	ACAERE	Intermediate	9	9	25	2	6	29	1.00	0.24	0.92	0.15	1.16	
	Acacia farnesiana	Camel bush, false mesquite	ACAFAR	Increaser		8	0	0	29	29				1.00		
	Acacia grasbyi	Miniritchie	ACAGRA	Intermediate	30	32	54	1	11	64	1.07	0.20	0.98	0.10	1.19	
	Acacia hemignosta	Club leaf wattle	ACAHEM	Intermediate	1	1	1	0	0	1	1.00	0.00	1.00	0.00	1.00	
	Acacia jennerae	Gum wattle	ACAJEN	Intermediate	1	1	4	0	0	4	1.00	0.00	1.00	0.00	1.00	
	Acacia kempeana	Witchetty bush	ACAKEM	Intermediate	20	20	90	4	31	117	1.00	0.34	0.96	0.17	1.30	
	Acacia ligulata	Umbrella wattle	ACALIG	Intermediate	5	5	22	1	6	27	1.00	0.27	0.95	0.14	1.23	
ACALIN	*Acacia linophylla*	Bowgada or wanyu	ACALIN	Intermediate	38	42	229	12	43	260	1.11	0.19	0.95	0.11	1.14	ACALIN
	Acacia murrayana	Fire or sand plain wattle, fire wattle	ACAMUR	Intermediate	4	4	9	0	2	11	1.00	0.22	1.00	0.10	1.22	
	Acacia pruinocarpa	Yalardy, gidgee	ACAPRU	Intermediate	28	29	57	13	19	63	1.04	0.33	0.77	0.27	1.11	
	Acacia pyrifolia	Kanji bush, ranji bush	ACAPYR	Decreaser	2	2	3	0	0	3	1.00	0.00	1.00	0.00	1.00	
	Acacia quadrimarginea	Murchison willow	ACAQUA	Intermediate	8	9	13	0	3	16	1.13	0.23	1.00	0.10	1.23	
ACARAM	*Acacia ramulosa*	Wanyu	ACARAM	Intermediate	76	76	450	8	65	507	1.00	0.14	0.98	0.08	1.13	ACARAM
	Acacia rhodophloia	Flat leafed miniritchie	ACARHO	Intermediate	4	4	18	1	3	20	1.00	0.17	0.94	0.11	1.11	
ACAROY	*Acacia roycei*	Needle myall	ACAROY	Intermediate	6	6	22	0	9	31	1.00	0.41	1.00	0.17	1.41	ACAROY
ACASCL	*Acacia sclerosperma*	Limestone wattle, silver bark wattle	ACASCL	Intermediate	26	33	107	6	97	198	1.27	0.91	0.94	0.34	1.85	ACASCL
	Acacia spinosissima		ACASPI		2	2	2	0	1	3	1.00	0.50	1.00	0.20	1.50	
	Acacia subtessarogona	Spreading gidgee	ACASUB	Intermediate	8	9	35	0	8	43	1.13	0.23	1.00	0.10	1.23	
ACATET	*Acacia tetragonophylla*	Curara	ACATET	Intermediate	280	326	1050	44	445	1451	1.16	0.42	0.96	0.20	1.38	ACATET
ACAVIC	*Acacia victoriae*	Prickly wattle or bardi bush	ACAVIC	Increaser	107	122	823	127	736	1432	1.14	0.89	0.85	0.38	1.74	ACAVIC
	Acacia wanyu		ACAWAN	Intermediate	2	4	11	0	7	18	2.00	0.64	1.00	0.24	1.64	
	Acacia wiseana	Kerosene bush	ACAWIS	Intermediate	7	7	12	1	1	12	1.00	0.08	0.92	0.08	1.00	
ACAXIP	*Acacia xiphophylla*	Snakewood	ACAXIP	Intermediate	36	36	132	2	45	175	1.00	0.34	0.98	0.15	1.33	ACAXIP
	Acanthocarpus preissii		ACNPRE	Intermediate	2	3	7	2	4	9	1.50	0.57	0.71	0.38	1.29	
	Alectryon oleifolius	Rosewood, mingah	ALEOLE	Decreaser	4	5	5	0	1	6	1.25	0.20	1.00	0.09	1.20	
	Alyogyne pinoniana	Sand plain hibiscus	ALGPIN	Increaser	1	1	12	4	2	10	1.00	0.17	0.67	0.27	0.83	
	Angianthus tomentosus	Camel-grass	ANGTOM		1	1	1	0	0	1	1.00	0.00	1.00	0.00	1.00	
	Asclepiadaceae family		ASCLEP	Decreaser	1	1	7	0	1	8	1.00	0.14	1.00	0.07	1.14	
ATRAMN	*Atriplex amnicola*	River saltbush, swamp saltbush	ATRAMN	Decreaser	13	12	514	182	75	407	0.92	0.15	0.65	0.28	0.79	ATRAMN
ATRBUN	*Atriplex bunburyana*	Silver saltbush	ATRBUN	Decreaser	82	81	2464	631	941	2774	0.99	0.38	0.74	0.30	1.13	ATRBUN
ATRNAN	*Atriplex nana*		ATRNAN		1	1	44	2	4	46	1.00	0.09	0.95	0.07	1.05	ATRNAN
	Atriplex nummularia	Old man saltbush	ATRNUM	Decreaser	6	5	22	1	0	21	0.83	0.00	0.95	0.02	0.95	
ATRSTI	*Atriplex stipitata*	Mallee saltbush	ATRSTI	Increaser	1	1	32	1	2	33	1.00	0.06	0.97	0.05	1.03	ATRSTI
ATRVES	*Atriplex vesicaria*	Bladder saltbush	ATRVES	Decreaser	60	58	2041	220	340	2161	0.97	0.17	0.89	0.13	1.06	ATRVES
	Brachychiton gregorii	Kurrajong	BRYGRE	Decreaser	1	1	1	0	0	1	1.00	0.00	1.00	0.00	1.00	
BRALAT	*Brachyscome latisquamea*	Broad bracted daisy	BRALAT	Decreaser	1	3	6	0	31	37	3.00	5.17	1.00	0.72	6.17	BRALAT
	Bursaria spinosa	Australian blackthorn	BURSPI	Intermediate	2	2	3	1	0	2	1.00	0.00	0.67	0.20	0.67	
	Casuarina cristata	Black oak	CSUCRI	Intermediate	3	3	3	0	1	4	1.00	0.33	1.00	0.14	1.33	
	Corymbia aspera	Rough leaf range gum	CORASP	Intermediate	1	1	2	0	0	2	1.00	0.00	1.00	0.00	1.00	
	Cratystylis conocephala	False blue bush	CRACON	Decreaser	1	1	1	0	0	1	1.00	0.00	1.00	0.00	1.00	
CRASUB	*Cratystylis subspinescens*	Sage	CRASUB	Decreaser	42	43	567	35	49	581	1.02	0.09	0.94	0.07	1.02	CRASUB
	Cryptandra connata		CRYCON	Intermediate	1	1	7	2	14	19	1.00	2.00	0.71	0.62	2.71	
	Cryptandra leucophracta		CRYLEU		1	1	2	0	0	2	1.00	0.00	1.00	0.00	1.00	
	Dianella revoluta	Native lily	DIAREV	Intermediate	21	22	48	3	21	66	1.05	0.44	0.94	0.21	1.38	
	Dicrastylis linearifolia	Cabbage bush	DCRLIN		1	1	17	4	1	14	1.00	0.06	0.76	0.16	0.82	
	Dodonaea lobulata		DODLOB	Intermediate	4	5	6	1	16	21	1.25	2.67	0.83	0.63	3.50	

Species with at least one popn having at least 20 individuals at either date 1 or date 2	Species name	Common name	Species Code	Response category	No_popn _D1	No_popn _D2	Initial	Number of plants that died	Number of recruits	Final	Occurrence ratio	Rec Rate	Survivorship	Turnover Rate	Population Growth Rate	Species with at least one popn having at least 20 individuals at either date 1 or date 2
	Dodonaea rigida	Thread-leaf hopbush	DODRIG		2	3	2	0	1	3	1.50	0.50	1.00	0.20	1.50	
	Dodonaea viscosa	Sticky hopbush	DODVIS	Intermediate		1	0	0	5	5				1.00		
	Eremophila aff. clarkei		ERMACL		1	1	3	0	1	4	1.00	0.33	1.00	0.14	1.33	
ERMACO	*Eremophila aff. compacta*		ERMACO	Decreaser	19	18	365	38	120	447	0.95	0.33	0.90	0.19	1.22	ERMACO
	Eremophila aff. georgei		ERMAGE		1	1	13	1	2	14	1.00	0.15	0.92	0.11	1.08	
ERMAGI	*Eremophila aff. gilesii*	Charleville turkey bush	ERMAGI	Increaser	1	2	79	35	18	62	2.00	0.23	0.56	0.38	0.78	ERMAGI
	Eremophila alternifolia	7410	ERMALT		1	1	1	0	1	2	1.00	1.00	1.00	0.33	2.00	
ERMCLA	*Eremophila clarkei*	Turpentine bush	ERMCLA	Intermediate	21	23	233	32	51	252	1.10	0.22	0.86	0.17	1.08	ERMCLA
ERMCOM	*Eremophila compacta*	Compact poverty bush	ERMCOM	Decreaser	31	32	232	27	58	263	1.03	0.25	0.88	0.17	1.13	ERMCOM
ERMCRE	*Eremophila crenulata*	Waxy-leaf poverty bush	ERMCRE	Increaser	14	14	175	29	39	185	1.00	0.22	0.83	0.19	1.06	ERMCRE
ERMCUN	*Eremophila cuneifolia*	Royal poverty bush	ERMCUN	Increaser	60	63	728	54	286	960	1.05	0.39	0.93	0.20	1.32	ERMCUN
	Eremophila decipiens		ERMDEC		2	2	6	1	2	7	1.00	0.33	0.83	0.23	1.17	
ERMERI	*Eremophila eriocalyx*	Desert pride, slender poverty bush	ERMERI	Decreaser	3	3	54	3	8	59	1.00	0.15	0.94	0.10	1.09	ERMERI
ERMEXI	*Eremophila exilifolia*	Little turpentine, poverty bush	ERMEXI	Intermediate	2	2	51	6	7	52	1.00	0.14	0.88	0.13	1.02	ERMEXI
ERMFOL	*Eremophila foliosissima*		ERMFOL	Intermediate	4	4	61	24	40	77	1.00	0.66	0.61	0.46	1.26	ERMFOL
ERMFOR	*Eremophila forrestii*	Wilcox bush or felt bush	ERMFOR	Intermediate	213	216	3272	313	854	3813	1.01	0.26	0.90	0.16	1.17	ERMFOR
ERMFRA	*Eremophila fraseri*	Turpentine bush	ERMFRA	Increaser	96	103	817	83	213	947	1.07	0.26	0.90	0.17	1.16	ERMFRA
ERMFRE	*Eremophila freelingii*	Rock fuchsia bush, stony poverty bush	ERMFRE	Increaser	18	19	89	18	36	107	1.06	0.40	0.80	0.28	1.20	ERMFRE
ERMGEO	*Eremophila georgei*	Fine-toothed poverty bush	ERMGEO	Intermediate	39	46	451	123	195	523	1.18	0.43	0.73	0.33	1.16	ERMGEO
ERMGIB	*Eremophila gibsonii*	Poverty bush	ERMGIB		1	1	22	3	2	21	1.00	0.09	0.86	0.12	0.95	ERMGIB
ERMGIL	*Eremophila gilesii*	Charleville turkey bush	ERMGIL	Increaser	16	16	416	94	232	554	1.00	0.56	0.77	0.34	1.33	ERMGIL
ERMGLA	*Eremophila glabra*	Black fuchsia, tar bush	ERMGLA	Intermediate	13	15	68	3	14	79	1.15	0.21	0.96	0.12	1.16	ERMGLA
ERMGLN	*Eremophila glandulifera*	ermapu ermaco	ERMGLN		2	2	108	10	91	189	1.00	0.84	0.91	0.34	1.75	ERMGLN
ERMGRA	*Eremophila granitica*	Thin-leaved poverty bush, wanderrie poverty bush	ERMGRA	Intermediate	29	28	269	48	193	414	0.97	0.72	0.82	0.35	1.54	ERMGRA
ERMHOM	*Eremophila homoplastica*		ERMHOM		3	3	51	4	43	90	1.00	0.84	0.92	0.33	1.76	ERMHOM
ERMLAA	*Eremophila laanii*	Murchison river poverty bush	ERMLAA	Decreaser	5	4	38	22	6	22	0.80	0.16	0.42	0.47	0.58	ERMLAA
ERMLAC	*Eremophila lachnocalyx*	Woolly calyxed eremophila, woolly poverty	ERMLAC	Intermediate	3	4	38	16	5	27	1.33	0.13	0.58	0.32	0.71	ERMLAC
ERMLAN	*Eremophila lanata*		ERMLAN		1	1	47	10	16	53	1.00	0.34	0.79	0.26	1.13	ERMLAN
ERMLAE	*Eremophila lanceolata*		ERMLAE		27	32	220	71	115	264	1.19	0.52	0.68	0.38	1.20	ERMLAE
ERMLAT	*Eremophila latrobei*	Warty-leaf eremophila, warty fuchsia bush	ERMLAT	Decreaser	116	125	553	54	198	697	1.08	0.36	0.90	0.20	1.26	ERMLAT
ERMLIN	*Eremophila linearis*	Saline fuchsia bush, harlequin fuchsia	ERMLIN		4	6	30	1	14	43	1.50	0.47	0.97	0.21	1.43	ERMLIN
ERMLON	*Eremophila longifolia*	Long-leaved poverty bush	ERMLON	Decreaser	9	15	13	1	29	41	1.67	2.23	0.92	0.56	3.15	ERMLON
ERMMAY	*Eremophila mackinlayi*	Poverty bush	ERMMAY	Intermediate	2	2	128	34	132	226	1.00	1.03	0.73	0.47	1.77	ERMMAY
ERMMAC	*Eremophila maculata*	Native fuchsia \ travel bush	ERMMAC	Intermediate	23	24	277	42	63	298	1.04	0.23	0.85	0.18	1.08	ERMMAC
ERMMAI	*Eremophila maitlandii*	Sand plain or tall poverty bush	ERMMAI	Intermediate	11	11	206	17	61	250	1.00	0.30	0.92	0.17	1.21	ERMMAI
ERMMAL	*Eremophila malacoides*	Frontage poverty bush	ERMMAL	Decreaser	8	9	51	0	34	85	1.13	0.67	1.00	0.25	1.67	ERMMAL
ERMMAR	*Eremophila margarethae*	Narrow leaf grey or sandbank poverty bush	ERMMAR	Increaser	48	49	1646	126	336	1856	1.02	0.20	0.92	0.13	1.13	ERMMAR
	Eremophila miniata	Kopi poverty bush	ERMMIN	Intermediate	4	5	16	2	2	16	1.25	0.13	0.88	0.13	1.00	
	Eremophila oldfieldii	Pixie bush, sub-Sp. angustifolia	ERMOLD	Decreaser	9	12	24	2	15	37	1.33	0.63	0.92	0.28	1.54	
	Eremophila oldfieldii ssp. angustissima	Poverty bush	ERMOSA		2	2	4	1	9	12	1.00	2.25	0.75	0.63	3.00	
	Eremophila pantonii	Limestone poverty bush	ERMPAN		1	1	3	0	0	3	1.00	0.00	1.00	0.00	1.00	
	Eremophila parvifolia		ERMPAR		3	3	20	0	3	23	1.00	0.15	1.00	0.07	1.15	
ERMPLA	*Eremophila platycalyx*	Granite poverty bush	ERMPLA	Intermediate	37	46	187	16	63	234	1.24	0.34	0.91	0.19	1.25	ERMPLA
ERMPTE	*Eremophila pterocarpa*	Silver poverty bush	ERMPTE	Intermediate	17	17	93	2	4	95	1.00	0.04	0.98	0.03	1.02	ERMPTE
ERMPUN	*Eremophila punicea*		ERMPUN	Increaser	14	13	270	32	69	307	0.93	0.26	0.88	0.18	1.14	ERMPUN
	Eremophila scoparia	Broom bush	ERMSCO	Intermediate	19	21	75	8	28	95	1.11	0.37	0.89	0.21	1.27	
	Eremophila serrulata	Green fuchsia bush	ERMSER	Increaser		2	0	0	2	2				1.00		
ERMSPA	*Eremophila spathulata*	Grey poverty bush, spoon leaf eremophila	ERMSPA		15	14	110	5	33	138	0.93	0.30	0.95	0.15	1.25	ERMSPA
ERMSPE	*Eremophila spectabilis*	Sand plain poverty, showy eremophila	ERMSPE	Intermediate	20	20	593	90	217	720	1.00	0.37	0.85	0.23	1.21	ERMSPE
ERMSTR	*Eremophila strongylophylla*	Poverty bush	ERMSTR	Decreaser	1	1	38	5	2	35	1.00	0.05	0.87	0.10	0.92	ERMSTR
	Eremophila youngii	Hook leaf poverty bush	ERMYOU	Intermediate	1	2	2	0	2	4	2.00	1.00	1.00	0.33	2.00	
	Eucalyptus eudesmioides	Mallalie	EUCEUD	Intermediate	1	1	1	0	0	1	1.00	0.00	1.00	0.00	1.00	
	Eucalyptus salmonophloia	Salmon gum	EUCSAM		1	1	1	0	0	1	1.00	0.00	1.00	0.00	1.00	
	Eucalyptus terminalis	Inland bloodwood	EUCTER	Intermediate	1	1	2	0	0	2	1.00	0.00	1.00	0.00	1.00	
	Exocarpos aphyllus	Broom bush, naked-lady	EXOAPH	Intermediate	9	8	10	1	6	15	0.89	0.60	0.90	0.28	1.50	
FRAPAU	*Frankenia pauciflora*		FRAPAU	Decreaser	3	3	190	8	22	204	1.00	0.12	0.96	0.08	1.07	FRAPAU
FRASPP	*Frankenia species*	Frankenia	FRASPP	Decreaser	112	122	3733	519	1107	4321	1.09	0.30	0.86	0.20	1.16	FRASPP
	Grevillea berryana	Sandy loam common	GRVBER	Intermediate	3	3	5	0	2	7	1.00	0.40	1.00	0.17	1.40	
	Grevillea brachystachya		GRVBRA		5	5	7	0	0	7	1.00	0.00	1.00	0.00	1.00	
GRVDEF	*Grevillea deflexa*	Spiny grevillea	GRVDEF	Decreaser	12	13	84	1	37	120	1.08	0.44	0.99	0.19	1.43	GRVDEF
	Grevillea eriostachya	Orange grevillea	GRVERI	Intermediate	2	2	6	0	4	10	1.00	0.67	1.00	0.25	1.67	
	Grevillea paradoxa		GRVPAR		3	3	7	0	0	7	1.00	0.00	1.00	0.00	1.00	

Species with at least one popn having at least 20 individuals at either date 1 or date 2	Species name	Common name	Species Code	Response category	No_popn _D1	No_popn _D2	Initial	Number of plants that died	Number of recruits	Final	Occurrence ratio	Rec Rate	Survivorship	Turnover Rate	Population Growth Rate	Species with at least one popn having at least 20 individuals at either date 1 or date 2
	Grevillea stenobotrya	Rattle bush	GRVSTE	Intermediate	4	4	9	0	1	10	1.00	0.11	1.00	0.05	1.11	
	Grevillea striata	Beefwood	GRVSTR	Intermediate	13	16	37	5	23	55	1.23	0.62	0.86	0.30	1.49	
GUNQUA	*Gunniopsis quadrifida*	Pigface, sweet samphire or water bush	GUNQUA	Decreaser	20	20	136	51	24	109	1.00	0.18	0.63	0.31	0.80	GUNQUA
	Gymnema granitica		GYMGRA	Decreaser	1	1	3	0	0	3	1.00	0.00	1.00	0.00	1.00	
HAKPRE	*Hakea preissii*	Needle bush	HAKPRE	Increaser	76	95	249	11	166	404	1.25	0.67	0.96	0.27	1.62	HAKPRE
	Hakea recurva subsp.arida	Common hakea, needle bush type	HAKRAR	Increaser	2	2	2	0	0	2	1.00	0.00	1.00	0.00	1.00	
HAKSUB	*Hakea suberea*	Cork bark tree	HAKSUB	Decreaser	6	6	24	1	6	29	1.00	0.25	0.96	0.13	1.21	HAKSUB
HALDOL	*Halosarcia doleiformis*	Samphire	HALDOL		1	1	34	4	10	40	1.00	0.29	0.88	0.19	1.18	HALDOL
HALSPP	*Halosarcia species*	Samphire	HALSPP	Intermediate	36	33	571	112	159	618	0.92	0.28	0.80	0.23	1.08	HALSPP
	Hemichroa diandra		HMCDRA			1	0	0	2	2				1.00		
HEMTYS	*Hemigenia tysonii*		HEMTYS	Intermediate	2	2	40	35	0	5	1.00	0.00	0.13	0.78	0.13	HEMTYS
	Indigofera colutea		INDCOL		1	1	1	0	3	4	1.00	3.00	1.00	0.60	4.00	
INDMON	*Indigofera monophylla*		INDMON	Intermediate	5	9	46	11	35	70	1.80	0.76	0.76	0.40	1.52	INDMON
	Lamarchea hakeifolia	False paperbark	LAMHAK		2	2	10	0	0	10	1.00	0.00	1.00	0.00	1.00	
LAWHEL	*Lawrencia helmsii*	Dunna dunna	LAWHEL	Intermediate	1	1	20	1	5	24	1.00	0.25	0.95	0.14	1.20	LAWHEL
LAWSQU	*Lawrencia squamata*		LAWSQU	Intermediate	17	17	478	60	58	476	1.00	0.12	0.87	0.12	1.00	LAWSQU
	Lawrencia viridigrisea		LAWVIR		1	1	3	2	0	1	1.00	0.00	0.33	0.50	0.33	
LEPPLA	*Lepidium platypetalum*	peppercress	LEPPLA	Decreaser	1	1	46	15	12	43	1.00	0.26	0.67	0.30	0.93	LEPPLA
	Lepidium strongylophyllum		LEPSTR	Decreaser	1	1	1	0	1	2	1.00	1.00	1.00	0.33	2.00	
LYCAUS	*Lycium australe*	Water bush or Aust. Boxthorn	LYCAUS	Decreaser	13	14	52	2	5	55	1.08	0.10	0.96	0.07	1.06	LYCAUS
	Maireana amoena		MARAMO	Decreaser	5	4	22	2	5	25	0.80	0.23	0.91	0.15	1.14	
MARAPH	*Maireana aphylla*	Spiny bluebush	MARAPH	Decreaser	12	12	225	12	123	336	1.00	0.55	0.95	0.24	1.49	MARAPH
MARATK	*Maireana atkinsiana*	Bronze bluebush	MARATK	Decreaser	15	14	76	5	9	80	0.93	0.12	0.93	0.09	1.05	MARATK
MARCON	*Maireana convexa*	Mulga bluebush	MARCON	Decreaser	45	46	559	245	360	674	1.02	0.64	0.56	0.49	1.21	MARCON
MARGEO	*Maireana georgei*	Golden bluebush, George's bluebush	MARGEO	Decreaser	132	147	2221	773	1597	3045	1.11	0.72	0.65	0.45	1.37	MARGEO
MARGLO	*Maireana glomerifolia*	Ball-leaf bluebush	MARGLO	Decreaser	43	42	474	34	25	465	0.98	0.05	0.93	0.06	0.98	MARGLO
	Maireana lobiflora	Flannel flower bluebush	MARLOB		1	1	9	0	0	9	1.00	0.00	1.00	0.00	1.00	
MARMEL	*Maireana melanocoma*	Pussy bluebush	MARMEL	Decreaser	19	22	306	123	270	453	1.16	0.88	0.60	0.52	1.48	MARMEL
	Maireana pentatropis	Erect bluebush	MARPEN	Intermediate		1	0	0	1	1				1.00		
MARPLA	*Maireana planifolia*	Flat bluebush, flat-leaf bluebush	MARPLA	Decreaser	119	119	1065	435	315	945	1.00	0.30	0.59	0.37	0.89	MARPLA
	Maireana planifolia x villosa		MARPXV		3	3	25	3	10	32	1.00	0.40	0.88	0.23	1.28	
MARPLT	*Maireana platycarpa*	Low bluebush, shy bluebush	MARPLT	Decreaser	45	42	1031	152	121	1000	0.93	0.12	0.85	0.13	0.97	MARPLT
MARPOL	*Maireana polypterygia*	Gascoyne bluebush	MARPOL	Decreaser	47	47	2246	92	500	2654	1.00	0.22	0.96	0.12	1.18	MARPOL
	Maireana prosthecochaeta		MARPRO		1	1	2	1	1	2	1.00	0.50	0.50	0.50	1.00	
MARPYR	*Maireana pyramidata*	Sago bush	MARPYR	Intermediate	134	135	3213	316	222	3119	1.01	0.07	0.90	0.08	0.97	MARPYR
MARSED	*Maireana sedifolia*	Pearl bluebush	MARSED	Intermediate	24	25	794	3	8	799	1.04	0.01	1.00	0.01	1.01	MARSED
	Maireana suaedifolia	Lax bluebush	MARSUE	Decreaser	1	1	9	5	2	6	1.00	0.22	0.44	0.47	0.67	
	Maireana thesioides	Climbing bluebush, lax bluebush	MARTHE	Decreaser	23	20	58	21	12	49	0.87	0.21	0.64	0.31	0.84	
	Maireana trichoptera	Downy bluebush	MARTRC	Decreaser	2		2	2	0	0		0.00	0.00	1.00	0.00	
MARVIL	*Maireana villosa*	Bluebush	MARVIL	Decreaser	120	143	906	382	629	1153	1.19	0.69	0.58	0.49	1.27	MARVIL
	Marsdenia australis	Cogla	MSDAUS	Decreaser		1	0	0	5	5				1.00		
	Melaleuca cardiophylla	Paper bark	MELCAR	Intermediate	1	1	3	0	0	3	1.00	0.00	1.00	0.00	1.00	
	Melaleuca uncinata	Broom honey myrtle	MELUNC	Intermediate	3	3	5	0	0	5	1.00	0.00	1.00	0.00	1.00	
	Mirbelia microphylla		MIRMIC	Intermediate	1	1	1	0	0	1	1.00	0.00	1.00	0.00	1.00	
	Mirbelia ramulosa		MIRRAM		3	3	23	0	7	30	1.00	0.30	1.00	0.13	1.30	
MIRSPI	*Mirbelia spinosa*		MIRSPI	Intermediate	12	12	103	20	31	114	1.00	0.30	0.81	0.24	1.11	MIRSPI
MUEFLO	*Muehlenbeckia florulenta*	Lignum / swamp bush	MUEFLO	Decreaser	3	2	22	2	81	101	0.67	3.68	0.91	0.67	4.59	MUEFLO
	Olearia muelleri	Muellers daisy bush, muellers daisy	OLEMUE	Intermediate	3	3	16	1	5	20	1.00	0.31	0.94	0.17	1.25	
OLEPIM	*Olearia pimeleoides*		OLEPIM		2	3	6	0	25	31	1.50	4.17	1.00	0.68	5.17	OLEPIM
PIMMIC	*Pimelea microcephala*	Mallee rice flower	PIMMIC	Intermediate	21	24	46	15	50	81	1.14	1.09	0.67	0.51	1.76	PIMMIC
PTOPHY	*Pittosporum phylliraeoides*	Desert willow, native willow	PTOPHY	Intermediate	2	1	27	27	1	1	0.50	0.04	0.00	1.00	0.04	PTOPHY
	Pityrodia paniculata		PITPAN		1	1	5	0	0	5	1.00	0.00	1.00	0.00	1.00	
	Psydrax attenuata		PSYATT		6	7	9	1	2	10	1.17	0.22	0.89	0.16	1.11	
	Psydrax latifolia	Native currant	PSYLAT	Decreaser	17	19	35	4	13	44	1.12	0.37	0.89	0.22	1.26	
PSYSUA	*Psydrax suaveolens*	Native currant	PSYSUA		28	36	85	8	45	122	1.29	0.53	0.91	0.26	1.44	PSYSUA
PTIBEA	*Ptilotus beardii*	Low mulla mulla	PTIBEA	Decreaser	3	3	101	1	1	101	1.00	0.01	0.99	0.01	1.00	PTIBEA
PTIDIV	*Ptilotus divaricatus*	Climbing mulla mulla	PTIDIV	Decreaser	19	21	80	18	53	115	1.11	0.66	0.78	0.36	1.44	PTIDIV
	Ptilotus exaltatus	Purple mulla mulla	PTIEXA	Decreaser	1		1	1	0	0		0.00	0.00	1.00	0.00	
PTIOBO	*Ptilotus obovatus*	Cotton bush	PTIOBO	Decreaser	468	497	14944	3763	7964	19145	1.06	0.53	0.75	0.34	1.28	PTIOBO
PTIPOL	*Ptilotus polakii*	Gascoyne mulla mulla	PTIPOL	Intermediate	45	46	1716	159	421	1978	1.02	0.25	0.91	0.16	1.15	PTIPOL
	Ptilotus rotundifolius	Royal mulla mulla	PTIROT	Decreaser	8	8	41	3	5	43	1.00	0.12	0.93	0.10	1.05	
PTISCH	*Ptilotus schwartzii*	Horse mulla mulla	PTISCH	Decreaser	102	108	2338	448	516	2406	1.06	0.22	0.81	0.20	1.03	PTISCH

Species with at least one popn having at least 20 individuals at either date 1 or date 2	Species name	Common name	Species Code	Response category	No_popn _D1	No_popn _D2	Initial	Number of plants that died	Number of recruits	Final	Occurrence ratio	Rec Rate	Survivorship	Turnover Rate	Population Growth Rate	Species with at least one popn having at least 20 individuals at either date 1 or date 2
RHADRU	*Rhagodia drummondii*	Low rhagodia	RHADRU		40	39	142	17	52	177	0.98	0.37	0.88	0.22	1.25	RHADRU
RHAERE	*Rhagodia eremaea*	Tall / climbing saltbush	RHAERE	Decreaser	263	296	984	204	563	1343	1.13	0.57	0.79	0.33	1.36	RHAERE
	Santalum acuminatum	Quandong, sweet quandong (rough fruit)	SANACU	Decreaser	2	7	2	0	5	7	3.50	2.50	1.00	0.56	3.50	
	Santalum lanceolatum	Bitter quandong, plumbush, plumwood (smooth fruit)	SANLAN	Decreaser	1	1	7	0	0	7	1.00	0.00	1.00	0.00	1.00	
	Santalum spicatum	Sandalwood	SANSPI	Decreaser	2	2	2	0	0	2	1.00	0.00	1.00	0.00	1.00	
	Sauropus crassifolius		SAUCRA		1	1	1	0	0	1	1.00	0.00	1.00	0.00	1.00	
SCVSPI	*Scaevola spinescens*	Currant bush, maroon bush	SCVSPI	Decreaser	98	99	555	25	203	733	1.01	0.37	0.95	0.18	1.32	SCVSPI
	Scaevola tomentosa	Ragged leafed scaevola, ragged leaf fan flower	SCVTOM	Decreaser	8	7	19	2	0	17	0.88	0.00	0.89	0.06	0.89	
SCLMED	*Sclerolaena medicaginoides*		SCLMED	Decreaser	4	4	97	2	7	102	1.00	0.07	0.98	0.05	1.05	SCLMED
	Senna aff.phyllodinea		SNNAPH		2	3	4	0	1	5	1.50	0.25	1.00	0.11	1.25	
SNNART	*Senna artemisioides*	Silver cassia	SNNART	Increaser	11	15	63	8	144	199	1.36	2.29	0.87	0.58	3.16	SNNART
SNNASX	*Senna artemisioides ssp. x sturtii*		SNNASX	Increaser	123	133	956	248	494	1202	1.08	0.52	0.74	0.34	1.26	SNNASX
SNNSAR	*Senna artemisioides subsp. x artemisioides*		SNNSAR	Increaser	23	22	56	7	33	82	0.96	0.59	0.88	0.29	1.46	SNNSAR
SNNASS	*Senna artemisioides subsp. x coriacea*	Desert cassia	SNNASS	Increaser	38	52	153	24	133	262	1.37	0.87	0.84	0.38	1.71	SNNASS
SNNSTU	*Senna artemisioides subsp. x sturtii*	Variable cassia	SNNSTU	Increaser	72	88	261	34	162	389	1.22	0.62	0.87	0.30	1.49	SNNSTU
SNNHEL	*Senna artemisioides subsp.helmsii*	Crinkle-leaf cassia, crinkled cassia	SNNHEL	Increaser	176	185	1176	196	662	1642	1.05	0.56	0.83	0.30	1.40	SNNHEL
SNNOLI	*Senna artemisioides subsp.oligophylla*	Blood bush	SNNOLI	Increaser	53	60	809	307	455	957	1.13	0.56	0.62	0.43	1.18	SNNOLI
SNNCHA	*Senna glutinosa ssp. chatelainiana*		SNNCHA	Decreaser	48	57	96	12	80	164	1.19	0.83	0.88	0.35	1.71	SNNCHA
SNNLUE	*Senna glutinosa subsp. x luerssenii*	White cassia	SNNLUE	Intermediate	5	7	20	1	27	46	1.40	1.35	0.95	0.42	2.30	SNNLUE
	Senna glutinosa subsp.charlesiana	Tall cassia	SNNCHR		1	1	1	0	0	1	1.00	0.00	1.00	0.00	1.00	
SNNPRU	*Senna glutinosa subsp.pruinosa*	Silver cassia, white cassia	SNNPRU	Decreaser	18	20	78	27	41	92	1.11	0.53	0.65	0.40	1.18	SNNPRU
SNNHAM	*Senna hamersleyensis*	Creeping cassia	SNNHAM	Decreaser	16	17	206	27	76	255	1.06	0.37	0.87	0.22	1.24	SNNHAM
SIDCAL	*Sida calyxhymenia*	Tall sida	SIDCAL	Decreaser	89	79	406	115	93	384	0.89	0.23	0.72	0.26	0.95	SIDCAL
	Solanum esuriale	Quena	SOLESU	Increaser	5	2	13	11	1	3	0.40	0.08	0.15	0.75	0.23	
SOLLAS	*Solanum lasiophyllum*	Flannel bush	SOLLAS	Intermediate	436	456	3281	1330	2407	4358	1.05	0.73	0.59	0.49	1.33	SOLLAS
	Solanum orbiculatum	Tomato bush	SOLORB	Increaser	29	37	60	15	29	74	1.28	0.48	0.75	0.33	1.23	
	Solanum sturtianum		SOLSTU	Intermediate	1	1	1	0	3	4	1.00	3.00	1.00	0.60	4.00	
	Spartothamnella puberula		SPAPUB		1	1	9	1	0	8	1.00	0.00	0.89	0.06	0.89	
SPATEU	*Spartothamnella teucriiflora*	Broom bush	SPATEU	Intermediate	74	83	295	22	172	445	1.12	0.58	0.93	0.26	1.51	SPATEU
STYSPA	*Stylobasium spathulatum*	Pebble bush	STYSPA	Intermediate	20	20	119	33	31	117	1.00	0.26	0.72	0.27	0.98	STYSPA
	Thryptomene decussata		THRDEC	Intermediate	2	2	18	1	0	17	1.00	0.00	0.94	0.03	0.94	
	Thryptomene maisonneuvei		THRMAI		1	1	17	2	0	15	1.00	0.00	0.88	0.06	0.88	
	Trianthema triquetra	Red spinach weed	TIATRI		1	1	7	0	8	15	1.00	1.14	1.00	0.36	2.14	
	Tribulus platypterus	Corkwood, corky bark caltrop	TRBPLA	Decreaser	2	1	3	2	2	3	0.50	0.67	0.33	0.67	1.00	
				TOTALS	**5,890**	**6,324**	**72,654**	**13,525**	**28,673**	**87,802**						

Attachment 4 – The Western Australian Rangeland Monitoring System (WARMS) grassland sites – vegetation data

These results apply to WARMS grassland sites only. Attachment 3 refers to WARMS shrubland sites and Attachment 5 to Landscape Function Analysis data. Background details on WARMS are found in Attachment 2.

Data set

- WARMS database as at 30/6/2004
- 69 grassland sites reassessed from a total of 71 grassland sites in the ACRIS region on 30 stations.
- 40 sites have been assessed three times (installation plus two reassessments). These times are referred to as T1, T2 and T3.
- 71 sites have been assessed at least once (T1), 69 sites have been assessed at least twice (T2) and 40 sites have been assessed three times (T3).
- Average time between installation and first reassessment was 4.2 years but ranged from 2.8 years to 6.0 years.
- Average time between first reassessment and second reassessment was 2.8 years and ranged from 2.8 years to 2.9 years.
- Earliest date of first sampling (T1) was 17/5/1994 and latest date of first sampling was 19/10/2001.
- Earliest date of second sampling (T2) was 13/8/1999 and the latest date of second sampling was 22/6/2002.
- Earliest date of third sampling (T3) was 18/6/2002 and the latest date of third sampling was 2/7/2002.

Change in frequency

The majority of grassland sites showed “no change” in frequency (Table 4:1). No change is defined as between 0.90 and 1.10 of the initial frequency. More sites declined than improved. This set of 44 sites are those which were sampled in each of the last two assessment periods, T2 and T3. The majority of these (41 of 44) were sampled in 1999 and 2002.

Table 4:1. Percentage of WARMS grassland sites showing decline, no change or improvement, using all perennial species, perennial grasses and perennial grass Decreasers only. The two periods from which change information was derived were sites sampled in 1997 or 1998 or 1999 and sites sampled in 2000 or 2001 or 2002.

Seasonal quality	Species included	Decline Frequency < 0.90	No change 0.90>= Frequency <1.10	Improvement Frequency >=1.10	Number of sites
Above average	All perennials	23	68	9	44
	Perennial grasses	25	66	9	44
	Perennial grass Decreasers	29	52	19	42
	Perennial grass Intermediates	n/a	n/a	n/a	7
	Perennial grass Increasers	n/a	n/a	n/a	3
Average	No sites				
Below average	No sites				

Of the 71 Grassland sites sampled, 40 have been sampled three times, i.e. installation and two reassessments. The periods were:

- Time 1 – 1994, 1995 or 1996.
- Time 2 – 1997, 1998 or 1999.
- Time 3 – 2000, 2001 or 2002.

When considering all perennial species, seven out of 40 sites showed decreased frequency at both reassessments, i.e. 33 of 40 showed an increase in frequency for at least one sampling. The decline in frequency was most common between the second and third sampling, 28 of 40 showed a decreased frequency. Ten of these sites decreased below 90 per cent of the previous frequency (Figure 4:1).

Similar results were found when only perennial grass species were considered (Figure 4:2). Six out of 40 sites showed decreased frequency at both samplings, 27 out of 40 had decreased frequency between the second and third sampling. Ten of these decreased below 90 per cent.

Figure 4:1 Change in frequency of all perennial species between installation (T1) and the second and third reassessments, T2 and T3 (n=40).

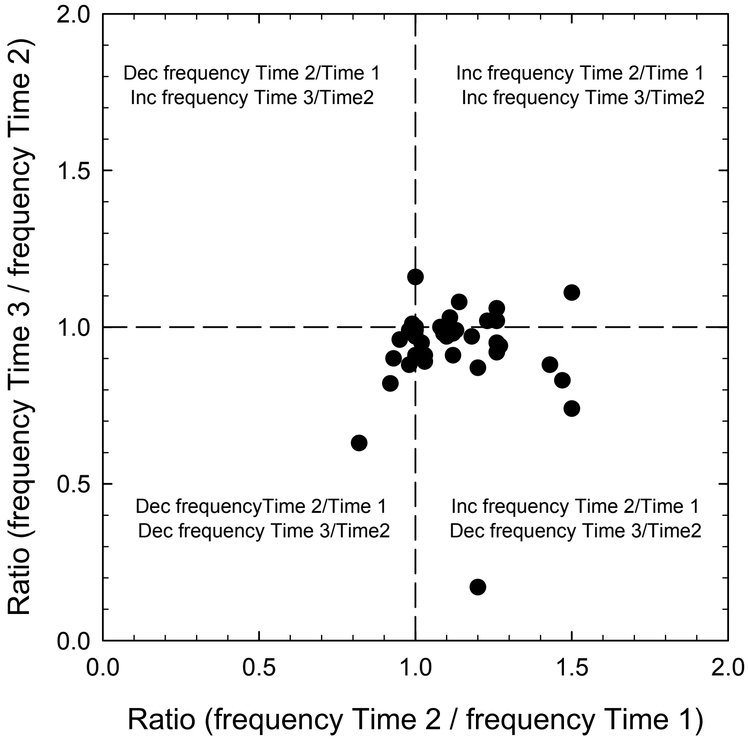
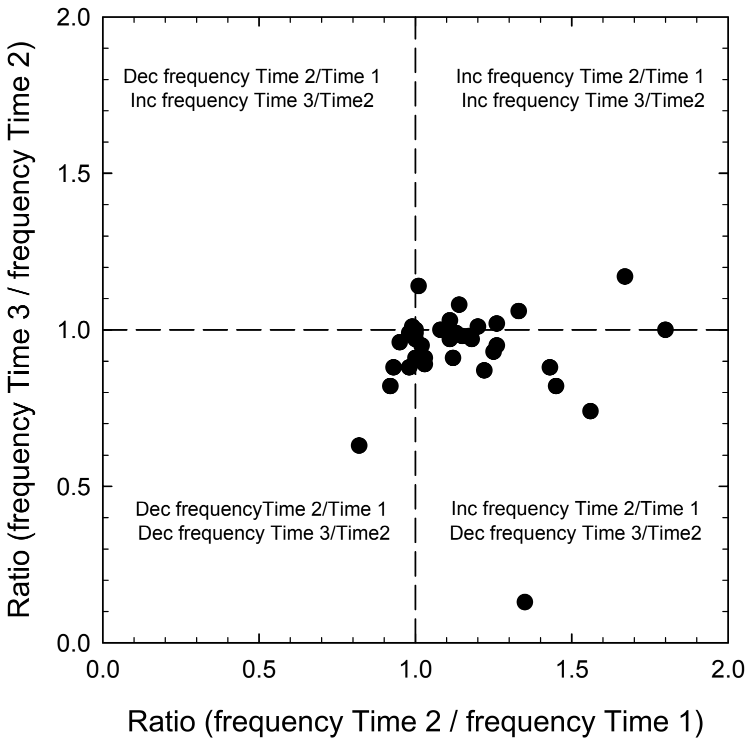


Figure 4:2. Change in frequency of all perennial grass species between installation (T1) and the second and third reassessments, T2 and T3 (n=40).



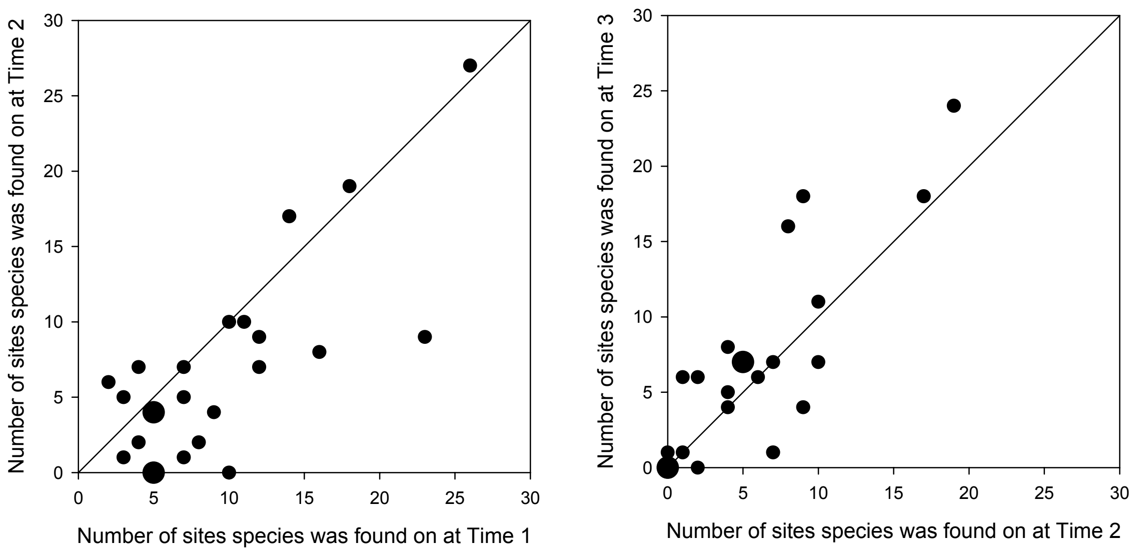
Occurrence ratio

Occurrence Ratio is defined as the number of sites a species was found on at a specific sampling date divided by the number of sites the species was found on at the previous sampling date. The metric provides an indication of change in local distribution. When greater than 1.0 it suggests the species distribution has expanded; when less than 1.0 it suggests the species distribution has contracted, at least within the representative areas sampled by WARMS.

Of the 24 species found on at least five sites at T1, T2 or T3:

- 16 of 24 had an occurrence ratio of less than 1 between T1 and T2.
- Four of 21 had an occurrence ratio of less than 1 between T2 and T3.
- Two of 21 had an occurrence ratio of less than 1 between both T1 and T2 and between T2 and T3.

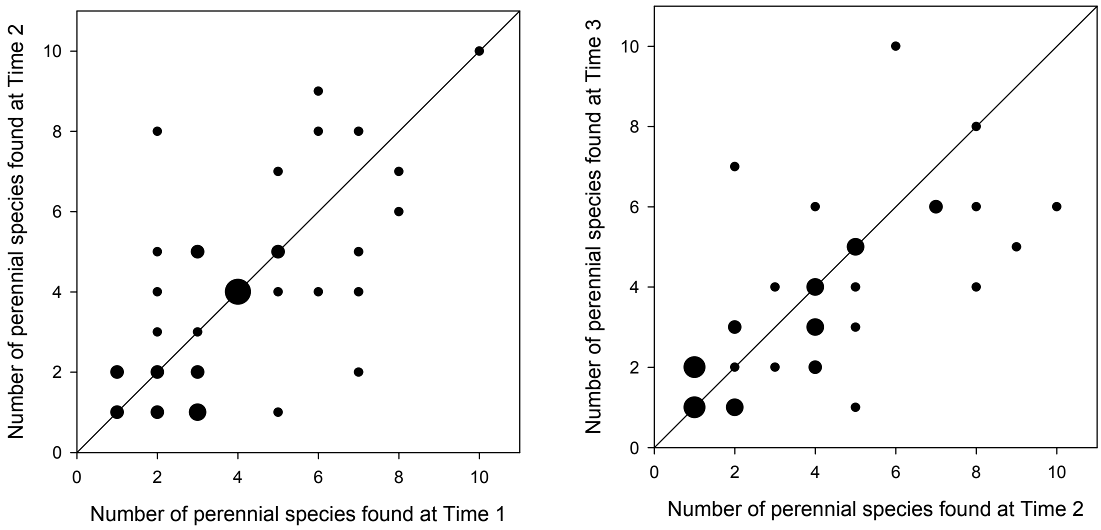
Figure 4:3. Frequency of occurrence of perennial species on WARMS grassland sites. Left pane – Time 1 to Time 2. Right pane – Time 2 to Time 3. Bubble size represents number of sites at each x,y point.



Species richness

Fifteen of 40 sites were less species rich at Date 2 than Date 1 and 18 of 40 sites were less species rich at Date 3 than Date 2. Only 3 of 40 declined over both assessment intervals while 2 of 40 increased or remained stable over both intervals (Figure 4:4).

Figure 4:4. Species richness, the number of species on each site between assessment dates - grassland sites. Bubble size represents number of sites at each x,y point. Left pane - Time 1 to Time 2. Right pane - Time 2 to Time 3.



Crown cover

The Crown cover ratio is the ratio of cover of woody perennials (taller than 1 m) at Time 3 compared to Time 2. It is difficult to ascribe a value judgement of improvement or decline to crown cover because this depends on the species contributing to the change. For the set of 42 WARMS grassland sites sampled at both T2 and T3, cover increased (i.e. >=1.10) on 64% (Table 4:2). Cover declined on 21% of sites and only 14 per cent showed stability (i.e. ratio between 0.90 and 1.10), showing how dynamic crown cover is on grassland sites.

Crown cover increased on 30 of 42 sites.

Table 4:2. Crown cover of woody perennials on WARMS grassland sites sampled at Time 2 and Time 3.

Seasonal quality	Species included	Cover ratio < 0.90	0.90>= Cover ratio <1.10	Cover ratio >=1.10	Number of sites
Above average	All woody perennials	21%	14%	64%	42
Average	No sites				
Below average	No sites				

Attachment 5 – The Western Australian Rangeland Monitoring System (WARMS) Landscape Function Analysis

These results apply to WARMS Landscape Function Analysis data only, including both shrubland and grassland sites. Separate attachments refer to vegetation data from WARMS shrubland sites (Attachment 3) and WARMS grassland sites (Attachment 4).

Data set

- WARMS database as at 30/6/2004
- Useful time sequential data were available for 398 shrubland sites out of 700 sampled and for 47 grassland sites out of 71 sampled.
- For grassland sites, the most recent two assessments were used to calculate ratios. In most cases these were calculated from T3 and T2 (see Attachment 2) but in others the ratio was calculated on T2 and T1 assessments.
- Assessment dates and periods between assessments are those presented for WARMS shrubland and grassland vegetation data.

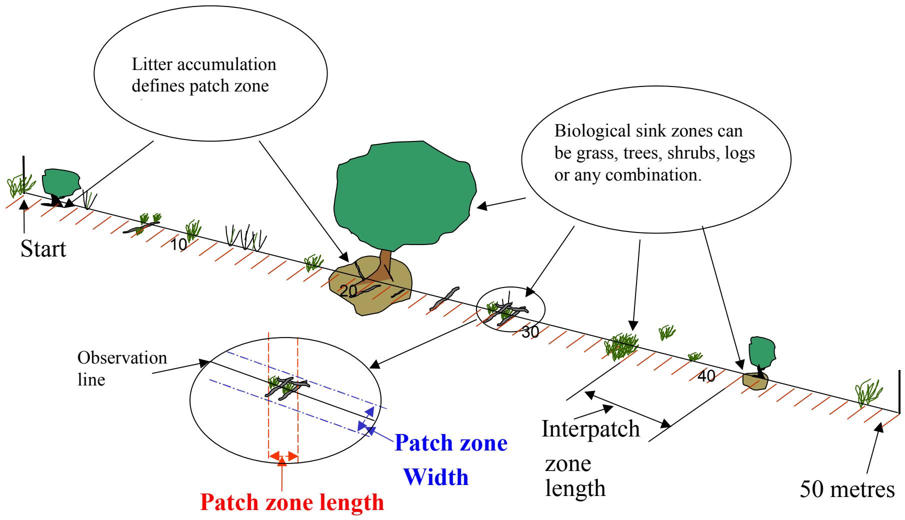
Landscape Function Analysis

The standard CSIRO Landscape Function Analysis technique is used on WARMS sites. On shrubland sites the technique of Tongway (1994) is used, while on grassland sites Tongway and Hindley (1995) is used. There are some minor differences between the two published methods but they are not sufficient to prevent summaries based on aggregated shrubland and grassland data.

Landscape function is assessed in a two step process. Firstly, the spatial organisation of the landscape is classified into patches (which regulate the flow of nutrients and water) and interpatches (which shed water and nutrients, often rapidly). Secondly, soil surface indicators are assessed along the central transect for individual quadrats characterised into patch types (Tongway 1994) or patch types (Tongway and Hindley 1995).

The spatial organisation of the patches (e.g. shrubs, logs, perennial grass butts) and interpatches (e.g. remnant bush mounds, bare ground) are recorded along the middle (i.e. 2nd) transect of the WARMS site. This provides an assessment of the number of patches and their average length and width (Figure 5.1).

Figure 5.1. Patch, interpatch organisation as assessed along the central transect. (Reproduced with the kind permission of David Tongway, CSIRO)



Once the spatial organisation has been recorded a range of soil surface indicators are assessed within 1 m^2 quadrats (Tongway 1994) or representative patches (Tongway and Hindley 1995) along the transect. These are then combined into indices of landscape function representing stability, water infiltration rate and nutrient cycling (Figure 5.2).

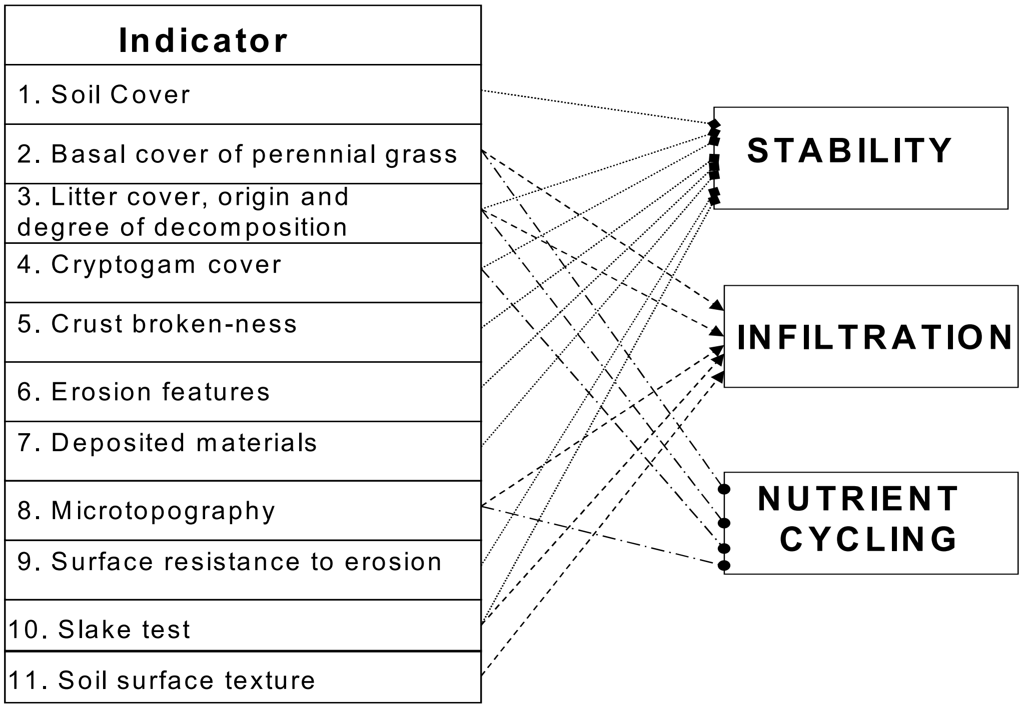
The **stability index** represents the ability of the soil to withstand erosive forces and to reform after disturbance.

The **infiltration index** provides an indication of how well water can soak into the soil, rather than running off downslope.

The **nutrient cycling** index shows how well organic matter is being cycled back into the system.

The stability, infiltration and nutrient cycling indices are not independent, with some indicators being used to calculate two indices (Figure 5.2).

Figure 5.2. Soil surface attributes assessed in quadrats along the central transect and combined into indicators of landscape function. The example shown is for a grassland site. (Reproduced with the kind permission of David Tongway, CSIRO).



Summarised data are presented below using the resource capture index and proportional landscape function derived from Holm (2001).

Resource capture index

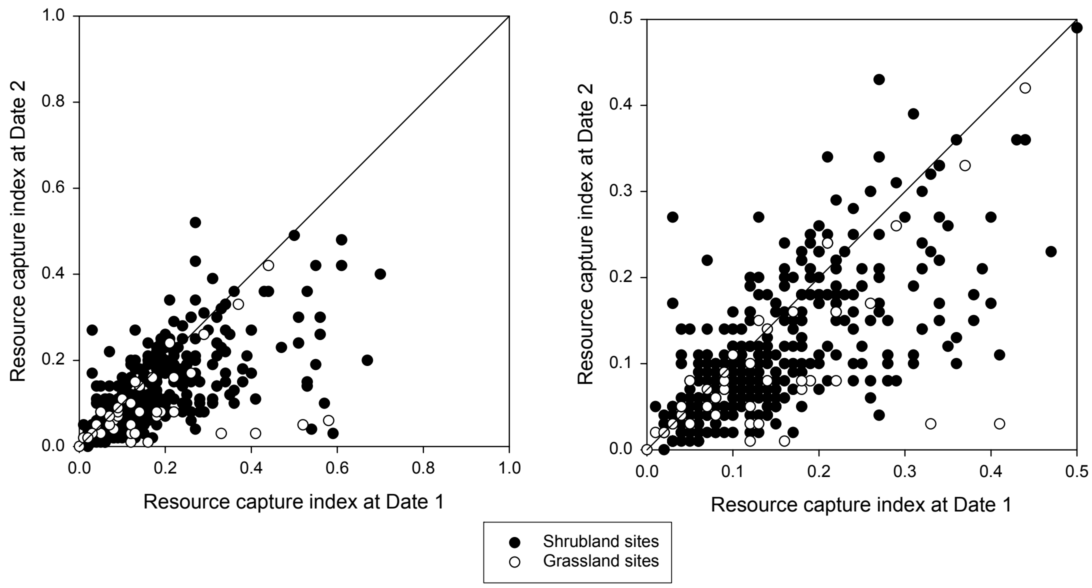
The resource capture index is a measure of the proportion of each transect occupied by resource capturing patches, as distinct from resource shedding patches, i.e. the proportion of the transect which is able to regulate nutrient and water flow.

Patch types within the WARMS dataset are characterised into whether they are resource capturing or resource shedding. The resource capture index is calculated as the total length of resource capturing patches, divided by the total length of the soil transect.

The resource capture index is considered relatively intransient, not easily altered due to recent seasonal conditions.

An increase in the resource capture index between two sampling dates represents an improvement.

Figure 5.3. Change in resource capture index. The left pane shows all data. The right pane is an expanded view, set at an index maximum of 0.5.



On shrubland sites, the resource capture index remained the same or increased on 123 of 392 sites (31 per cent). The index decreased on the other 269 sites (Figure 5.3). On grassland sites 16 of 45 remained the same or increased.

Table 5:1. Resource capture index. Percentage of sites showing decline, no change or improvement following above average, average or below average seasonal conditions.

Seasonal quality	Site type	Decline Ratio between dates < 0.90	No change 0.90>= Ratio between dates < 1.10	Improvement Ratio between dates >= 1.10	Number of sites
Above average	Shrubland	74%	7%	19%	156
	Grassland	55%	20%	25%	44
	Pooled	*70%*	*10%*	*20%*	*200*
Average	Shrubland	57%	18%	25%	130
	Grassland	na	na	na	1
	Pooled	*na*	*na*	*na*	*131*
Below average	Shrubland	57%	20%	23%	105
	Grassland	na	na	na	0
	Pooled	*na*	*na*	*na*	*105*

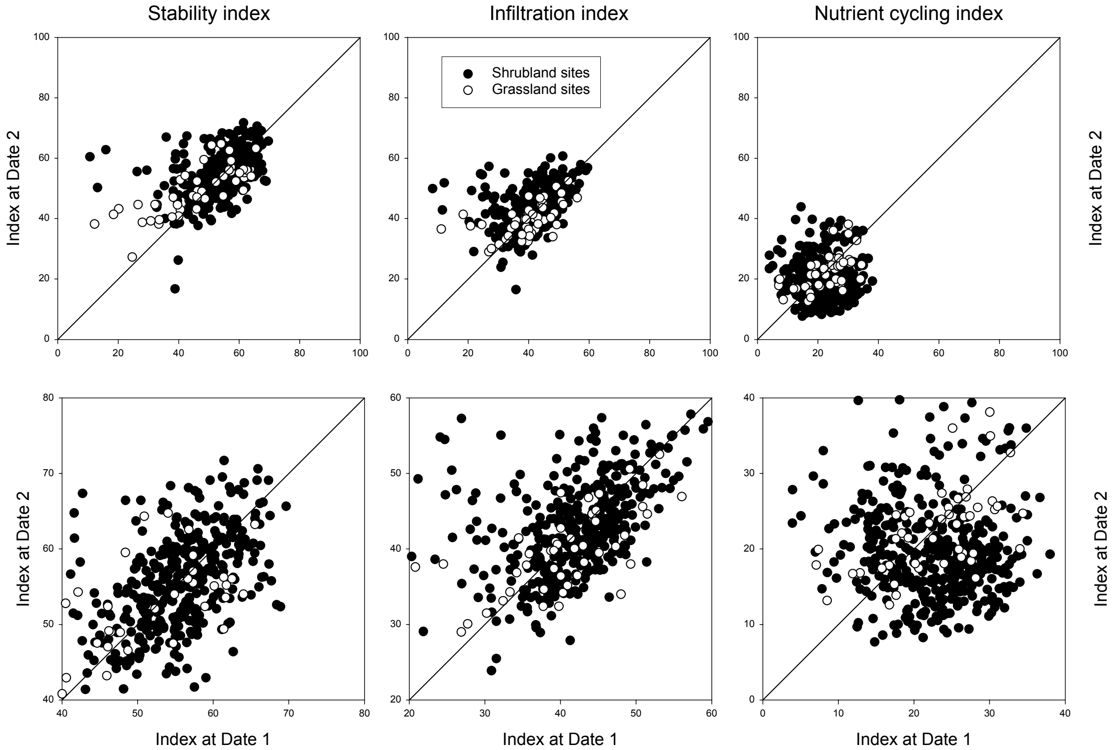
Proportional landscape function

Stability, nutrient cycling and infiltration indices were calculated for each patch type on each site. The proportional landscape function provides weighted averages for the whole site based on the proportion of the transect containing each of the patch types. That is, it summarises the three indices for the whole site rather than for individual patch types on the site.

Holm (2001) considered that changes in the:
- Nutrient cycling index are likely to be seasonally dependent.
- Infiltration index reflects changes in a mixture of seasonally dependent and relatively seasonally independent attributes.
- Stability index are related to both changes in grazing and are relatively independent of seasons.

Therefore, for the purposes of ACRIS reporting more weight should be given to the stability index than for the infiltration or nutrient cycling indices.

Figure 5.4. Proportional landscape function for the three indices. The top three panes show all data. The bottom three panes provide expanded views.



The stability index remained the same or increased on 201 of 398 shrubland sites and 29 of 47 grassland sites (Figure 5.4). The infiltration index remained the same or increased on 189 of 398 shrubland sites and 25 of 47 grassland sites. The nutrient cycling index remained the same or increased on 142 of 398 shrubland sites and 24 of 47 grassland sites.

Table 5.2. Proportional landscape function – stability index. Percentage of sites showing decline, no change or improvement following above average, average or below average seasonal conditions.

Seasonal quality	Site type	Decline Ratio between dates < 0.90	No change 0.90>= Ratio between dates < 1.10	Improvement Ratio between dates >= 1.10	Number of sites
Above average	Shrubland	13%	53%	34%	162
	Grassland	15%	50%	34%	46
	*Pooled**	*13%*	*52%*	*34%*	*208*
Average	Shrubland	15%	73%	13%	131
	Grassland	na	na	na	1
	Pooled	*na*	*na*	*na*	*132*
Below average	Shrubland	21%	70%	9%	105
	Grassland	na	na	na	0
	Pooled	*na*	*na*	*na*	*105*

** Pooled is the weighted average of the values from the shrubland and grassland sites*

Table 5.3. Proportional landscape function – infiltration Index. Percentage of sites showing decline, no change or improvement following above average, average or below average seasonal conditions.

Seasonal quality	Site type	Decline Ratio between dates < 0.90	No change 0.90>= Ratio between dates < 1.10	Improvement Ratio between dates >= 1.10	Number of sites
Above average	Shrubland	12%	51%	38%	162
	Grassland	30%	59%	11%	46
	*Pooled**	*16%*	*52%*	*32%*	*208*
Average	Shrubland	16%	65%	19%	131
	Grassland	na	na	na	1
	Pooled	*na*	*na*	*na*	*132*
Below average	Shrubland	34%	61%	5%	105
	Grassland	na	na	na	0
	Pooled	*na*	*na*	*na*	*105*

** Pooled is the weighted average of the values from the shrubland and grassland sites*

Table 5.4. Proportional landscape function – nutrient cycling Index. Percentage of sites showing decline, no change or improvement following above average, average or below average seasonal conditions.

Seasonal quality	Site type	Decline Ratio between dates < 0.90	No change 0.90>= Ratio between dates < 1.10	Improvement Ratio between dates >= 1.10	Number of sites
Above average	Shrubland	23%	14%	64%	162
	Grassland	41%	26%	33%	46
	*Pooled**	*27%*	*16%*	*57%*	*208*
Average	Shrubland	70%	19%	11%	131
	Grassland	na	na	na	1
	Pooled	*na*	*na*	*na*	*132*
Below average	Shrubland	95%	3%	2%	105
	Grassland	na	na	na	0
	Pooled	*na*	*na*	*na*	*105*

** Pooled is the weighted average of the values from the shrubland and grassland sites*

Attachment 6 - Capacity for change

Introduction

Much of the information for this attachment comes from the Annual Report (including Final report) of the Gascoyne - Murchison Strategy (Department of Agriculture Western Australia 2004), the independent evaluation of the Strategy (URS 2004) and several other reports written for the Strategy. It also includes information on change in enterprise type and change in livestock numbers.

The Gascoyne – Murchison Strategy was launched in April 1998. It was designed to foster a *'socially and economically viable community involved in a diverse range of industries, based on the use of the rangelands in an environmentally sustainable way'* (Department of Agriculture Western Australia 2004).

The Strategy was designed to have an impact at the individual level as well as the business or enterprise level and at a regional level. It did this through four components, Business and Industry Development Grants, Industry Research and Development, Voluntary Lease Adjustment and Regional Environmental Management.

There is considerable geographical overlap between the Gascoyne – Murchison Strategy area and the Gascoyne – Murchison region used in this pilot project, despite the fact that the Gascoyne – Murchison Strategy area was based on local government boundaries (Gascoyne – Murchison Rangeland Strategy Steering Group 1997) while the ACRIS pilot region was based on IBRA sub-region boundaries. The major difference is that the south-east boundary of the Gascoyne – Murchison Strategy area is the Sandstone Shire boundary while the ACRIS pilot region boundary continues through parts of the Leonora, Menzies and Boulder Shires almost to the town of Kalgoorlie. The Gascoyne – Murchison Rangeland Strategy Steering Group (1997) states that there were 253 leases in the Gascoyne – Murchison Strategy area, while the ACRIS pilot region has about 290 leases.

The Strategy was independently evaluated by both interviewing landholders in the region and by examining Strategy documentation (URS 2004). A baseline survey was also conducted in 1999 (Dames and Moore – NRM 1999) so that the final evaluation was able to make some judgements about changes in capacity over the five year period 1999 – 2004. About 50% of the landholders in the Strategy area were interviewed directly in the 1999 survey. The 2004 survey aimed to re-interview as many of these as possible. Changes in lease ownership, contact details and respondent availability meant that only a potential 107 landholders could be surveyed. The 2004 survey sampled 92 (85%) of these (URS 2004).

Engagement with Gascoyne – Murchison Strategy

About 70% of pastoral leaseholders were actively involved in the Gascoyne-Murchison Strategy (URS 2004). Of the URS sample, 58% had received financial assistance from the Strategy and 26% had participated in Strategy funded activities.

Institutional capacity

While government departments play less of a direct role in managing rangelands than on-ground managers, there remains a need for government policy and actions to be closely aligned across the range of departments. The Gascoyne – Murchison Strategy made significant progress towards this due to its coordination of the activities of 18 government departments (although the URS report (2004) noted that more could have been achieved). Perhaps the most important improvement in inter-departmental relations is that between the Departments of Agriculture and Conservation and Land Management.

A major policy outcome of the Strategy was a series of proposed policies (still under development, but see Department of Western Australia (2001) 'Managing the rangelands of Western Australia. A framework for the future' for an early draft) that aimed to provide a better institutional environment for the management of the rangelands, through an improved tenure system and through the establishment of a body to oversee the management of the rangelands (i.e. the Rangelands Council).

Structural adjustment

At both the regional and individual enterprise scale, managing sustainability is dependent on having viable leases. The Strategy Board identified very early that structural adjustment was critical to achieving this. During the course of the Gascoyne – Murchison Strategy about 26% of leases changed hands (about 5% per annum) and about 60% of those transfers involved properties where sustaining a stand-alone pastoral business would be difficult. The URS report (2004) suggested that these had slipped through the structural 'adjustment net'.

The Board set up a Voluntary Lease Adjustment process. Eighteen whole leases and 19 part leases were removed from the grazing industry by purchase for the conservation estate. A further four leases were adjusted between neighbours (Department of Agriculture Western Australia 2004). However, a number of businesses remain in need of substantial adjustment and this limits the capacity of the region to manage land optimally.

At a regional scale, structural adjustment has improved the capacity for conservation and has removed a number of unviable leases from the region (Department of Agriculture Western Australia 2004). By the end of 2004, 18 whole pastoral leases and 19 part leases (a total of 3,914,691 ha) were acquired for the conservation estate, giving a total of about 5,000,000 ha (or 8.8%) within the Strategy area (see Attachment 7).

Managerial capacity

Independent evaluation of the Strategy suggests that managerial capacity improved in about 50% of the businesses in the region following the Strategy's activities. This judgement was based on perceptions of viability, continued commitment to business planning that is self-financed, feeling that personal capacity to manage had improved and increased confidence in the future. There was also evidence that many people involved in the program were innovative, outward looking and more welcoming of new ideas (URS 2004).

A survey of pastoralists in the Strategy region showed that over the previous five years 58% of those interviewed stated their capacity to manage had improved, 25% said it had not changed and 17% said it had declined (URS 2004). A question that compared people's management confidence suggested this had improved since 1999. URS speculated that this may be because those with less confidence had left the industry over the last five years.

Managers were more optimistic about their own capacity to manage than they were about the regional or industry capacity. However, the proportion of people who believe that regional capacity is improving increased slightly from the 1999 survey (URS 2004). There were some sub-regional differences in this assessment and URS speculated that lower optimism may have been due to more severe seasonal conditions.

People's views on the future of the region did not change markedly from 1999 to 2004. In 2004, 39% said they were slightly to very confident and 61% said they were slightly to very worried. This suggests that while they perceived their capacity to have increased, they were still not overly confident about the future (URS 2004).

Between 1999 and 2004 peoples' confidence in their own future increased. When asked the reasons for their confidence a sample of responses suggested that stations were still making money despite the drought, that off-station income was easy to obtain and that they saw a future in which they could make money.

Based on a financial benchmarking project ran as part of the Gascoyne – Murchison Strategy, Bartle (2004) found that business management skills in the pastoral industry were poor and that even the basic tasks, like record keeping, were not done. This may be gradually changing. URS found that 50% of respondents had a business plan prepared in the last two years. This was an increase on 22% in the 1999 survey (Dames and Moore NRM 1999, URS 2004). Most of those surveyed in 2004 thought the business plan had been effective in increasing their viability.

Matching livestock numbers to feed supply

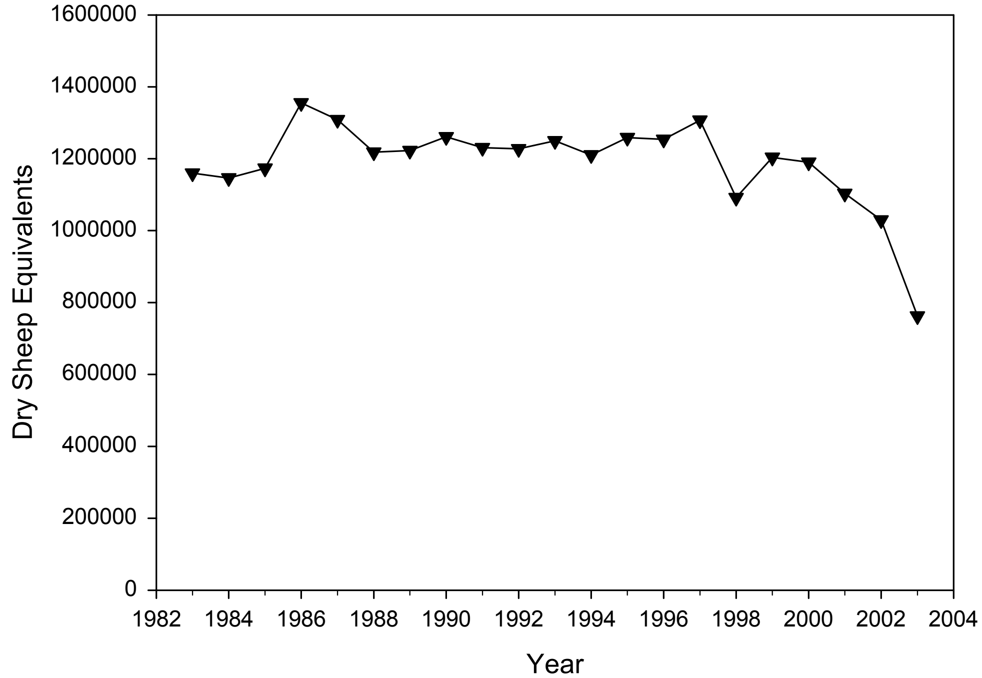
One of the most important indicators of pastoralists' ability to manage is that of making decisions that 'get the stocking rate right'. Bartle (2004) used the indicator of stocking rate relative to rainfall (DSE days per ha per 100 mm of rainfall) and found that this jumped from an average of 14 in 1999-00 to 21 in 2000-01 and then to 28 in 2001-02, suggesting that managers were not destocking fast enough as conditions dried out during the drought. Bartle's assessment was that stocking rates in 2001-02 were about double what they should have been.

However, livestock figures from the region suggest that numbers dropped substantially as a result of the drought (Figure 6.1). The average number of livestock between 1981-82 and 1996-97 was about 1.2 M DSE in the six shires shown. This fell to 760,000 by 2002-03, about 64% of the longer-term average.

These data were summarised from data provided by pastoralists to the Pastoral Lands Board ('Annual Return of Livestock and Improvements for Year Ending 30 June …', submitted under Section 113 of the Land Administration Act [1997]) and held within the Pastoral Lease Information System (PLIS) database. The selected Shires were those that experienced drought from the early 2000s (about 120 leases).

Large reductions in livestock numbers during drought do not necessarily imply good management. Previous droughts have shown that stock reductions are often due to losses on-station due to starvation (McKeon *et al.* 2004). However, there is good evidence that during the recent drought managers made decisions to remove livestock, before they died on-station (Figure 6.2).

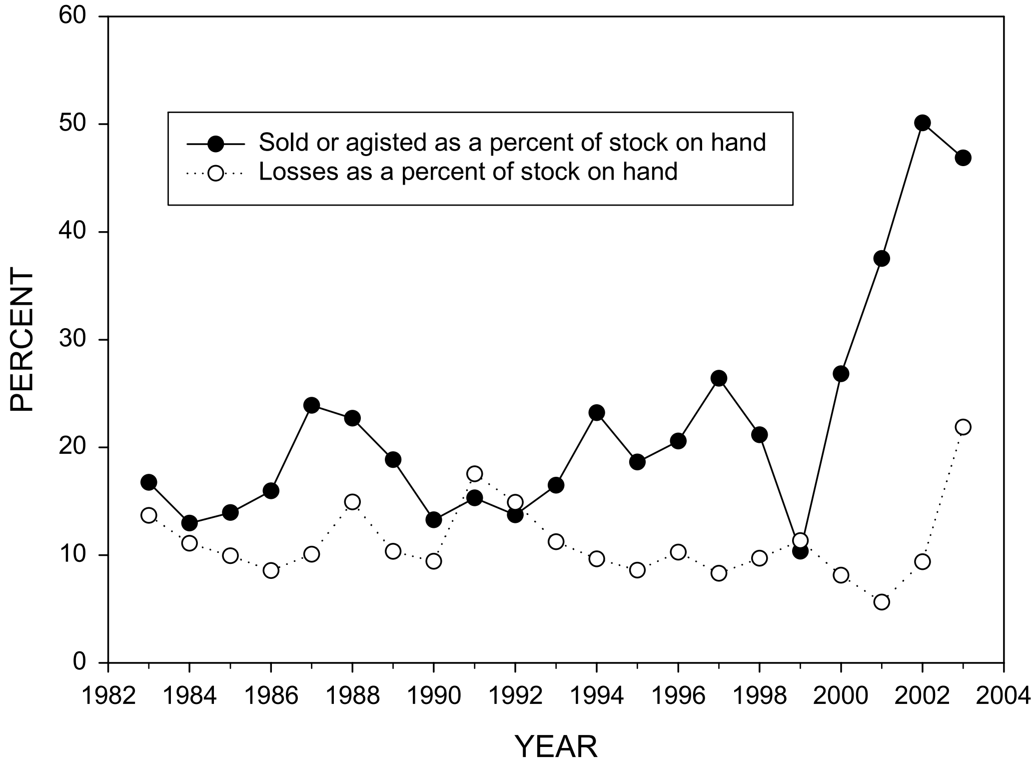
Figure 6.1. Livestock numbers (expressed as Dry Sheep Equivalents) within the Shires of Carnarvon, Cue, Mount Magnet, Murchison, Upper Gascoyne and Yalgoo. The x-axis year is the second year of each financial year couplet.



Losses during the first two years of the drought were comparable with losses over the period 1981-82 to 1996-97 (Figure 6.2). Even losses of nearly 22% in 2002-03 were much less than the losses reported in earlier severe droughts (McKeon *et al.* 2004).

This was almost certainly due to the high proportion of livestock that were sold or agisted from 1999-00 onwards. While the average between 1981-82 and 1996-97 was 18% of stock on hand, in the four years from to 1999-00 to 2002-03 the equivalent percentages were 27%, 37%, 50% and 47%. Good prices for livestock over this period undoubtedly made the decision to sell rather than hang-on an easier one.

Figure 6.2. Livestock reductions in the Carnarvon, Cue, Mount Magnet, Murchison, Upper Gascoyne and Yalgoo Shires. The x-axis year is the second year of each financial year couplet.



Enterprise changes

There has been a substantial shift in pastoral practice on many leases in the Gascoyne – Murchison Strategy region in the last five years (URS 2004). The URS survey found that about 76% of respondents had embarked on new activities. Nearly all the respondents stated that the activities had been beneficial. These activities included;

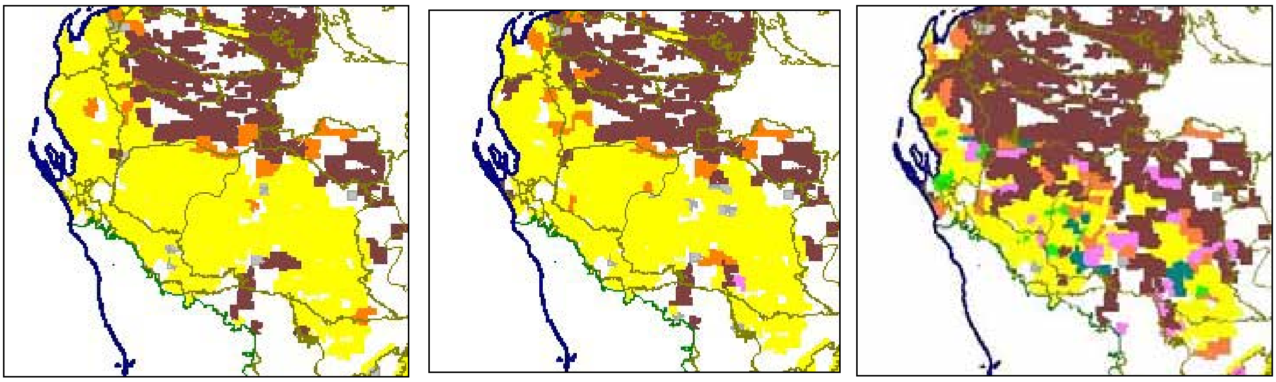
- homestead improvements,
- improved computer skills and hardware,
- improved occupational health and safety,
- land transfers,
- change in those responsible for management,
- general infrastructure changes,
- rotational grazing,
- reduced grazing pressure,
- change in stock type,
- change in flock or herd structure,
- increased feral animal control,
- diversification enterprises, including research and development,
- Ecosystem Management Unit (EMU) activities,
- Professional assistance from consultants
- Environmental Management Systems

In 2004, 23% of managers planned to make no long term changes in their business over the next five years (URS 2004). At the other end of scale, 9% gave the maximum score for preparedness to change. This contrasts with the 1999 survey in which 24% were prepared to make the maximum change and only 15% said they intended to maintain their business as is. URS concluded that the Strategy, changes in markets for commodities and seasonal fluctuations all contributed to the high level of change and that future changes would be less dramatic.

There have been large changes away from running Merino sheep for wool production to running cattle and/or a range of meat sheep such as damaras and dorpers as well as increased income from 'rangeland goats'. This has reduced the reliance on income from wool but has also led to a decline in the maintenance of infrastructure, particularly internal fencing. URS (2004) reported that 27 of 92 respondents (29%) had changed stock type in the last five years.

Data supplied by pastoralists to the Pastoral Lands Board, and held within PLIS, shows the large decline in the number of sheep enterprises since 1984, with a corresponding increase in cattle enterprises and the emergence of enterprises that now farm previously feral goats (Figure 6.3).

Figure 6.3. Change in livestock enterprise type between 1984, 1994 and 2004. Brown – cattle; yellow – sheep (Merino and/or meat breeds); orange – sheep and cattle; teal – managed goats; light green – sheep and managed goats; pink – destocked; and grey – no data available. Note that many sheep enterprises have a small number of cattle and vice versa. The attributions shown here represent the dominant income stream, except on those leases coloured orange where sheep and cattle both contribute significant amounts of income.



(a) 1984 (b) 1994 (c) 2004

The Strategy also promoted the identification and development of new industries as well as development of existing industries. More than forty projects involving pastoralists were funded to assist development opportunities (URS 2004). These included;

- station tourism on twelve properties,
- scoping and developing horticultural projects,
- aquaculture development on at least four properties,
- industry development, marketing and value adding of animal products,
- meat production from exotic (damara and dorper) sheep,
- trialling of irrigated fodder crops,

- development of on-line purchasing,
- development of tourist routes.

Technological or 'on-ground' capacity

Managing total grazing pressure

The capacity to manage total grazing pressure in the pilot region has drastically increased in the last few years due to the uptake of TGM (Total Grazing Management) yards. The Strategy facilitated the installation of 1,350 TGM yards, covering about 10 per cent of the artificial waters over some 17 million ha on 64 stations, which have significantly improved the capacity of pastoralists to manage grazing from livestock, feral animals and native grazers (Department of Agriculture Western Australia 2004). An unknown number of TGM yards were installed without direct Strategy support.

Water supplies were developed and reticulation improved at about 170 sites on 51 stations. About 770 km of new fencing on 18 stations was erected to protect fragile land systems as well as 360 km of strategic fencing for improved sheep control on 16 stations, 1,240 km for cattle control on 20 stations and 1,040 km for control of domesticated goats on 14 stations.

Control of artesian water

Artesian bore capping and reticulation within the Gascoyne – Murchison Strategy has drastically improved capacity to manage the underground water resource, saving an estimated 8.35 gigalitre of water per annum at the surface (Department of Agriculture Western Australia 2004).

The bore rehabilitation program;

- geophysically logged 43 artesian bores in the Carnarvon Basin,
- produced 19 artesian water management plans,
- completed the drilling and re-lining of 15 artesian bores,
- decommissioned or controlled 19 previously flowing bores,
- cement plugged 39 bores,
- saved an estimated 50 GL or water per annum including seepage and below surface loss and,
- replaced about 88 km of bore drains with underground piped reticulation which had a positive impact on the management of feral and domestic animals and the spread of weeds (Department of Agriculture Western Australia 2004).

Environmental Management Systems

Significant progress was made on the development of accountable management systems (EMS-type systems) both literally and in terms of pastoralist understanding of such systems (URS 2004).

An accredited Environmental Management System (under SQF 1000) was developed and three pastoral businesses were subsequently accredited (Taylor 2002).

Financial capacity

Many stations rely on non-pastoral activities to provide substantial parts of their income. In the URS survey, 75% of respondents received more than two-thirds of their income from pastoral activities, 12.5% between one-third and two-thirds and 12.5% less than one-third. Stations in the south-east were more likely to receive higher levels of non-pastoral income (URS 2004). Longley (2000) reported that 90% of businesses that submitted a grants application to the Gascoyne – Murchison Strategy obtained off-station and other income, with the average annual amount being $40,000. Cattle dominated leases obtained an average of $60,000 while sheep dominated leases achieved an average of $36,000.

Bartles' conclusion was that there were good levels of profitability across the region, despite the dry conditions (Bartle 2004). She found that in the 2001-02 financial year, 31 of the 47 businesses that participated in the benchmarking returned a profit, with the top 20% returning an average of 14.6% on assets managed. The average for the whole group was 3.7 per cent. This conclusion was reached before the impact of the prolonged dry period was significantly felt.

By contrast Longley (2000) found a more parlous situation in the region. Based on 78 grant applications made during the 1997 or 1998 calendar and fiscal years he found that 41% of the businesses were cashflow negative, that the average surplus cashflow was only $3,300 and that the average return on gross assets was 0.3 per cent. Longley noted that this financial situation was after five or six years of good or average seasons and he predicted that the onset of drought would have 'devastating social, economic and environmental effects.'

The contrast between Longley's results and those of Bartle's may be because Bartle's sample came from those businesses who chose to be included in the benchmarking project while Longley's came from data submitted by 78 businesses as part of a grant application process. Longley notes he was advised that that the applications represented 'a good cross section of the industry'.

Longley found considerable differences in the financial state between sheep dominated and cattle dominated enterprises, with sheep dominated enterprises being worse off (Longley 2000).

For the 58 sheep dominated businesses;

- The average cashflow was a loss of $1,640.
- The upper quartile showed a surplus of $53,000 and a return on gross assets of 4 per cent.
- The lower quartile showed a loss of just under $69,000.
- 43% of the businesses were cashflow negative.

For the 14 cattle dominated businesses (Longley advised caution with the small sample size);

- The average cashflow was over $23,000.
- The upper quartile showed a surplus of $75,000 and a return on gross assets of 6 per cent.

- The lower quartile showed a loss of $40,000.
- 29% of the businesses were cashflow negative.

Bartle (2004) found that approximately 45% of the stations benchmarked had an equity of greater than 90%, while 32% had less than 70% equity. Longley (2000) found that sheep dominated enterprises operated at 61% while cattle dominated enterprises averaged 87% equity.

It is difficult to make generalisations about the financial capacity of the pastoral industry in the Gascoyne – Murchison region. Both Bartle and Longley showed enormous variation between the best performing enterprises and the worst performing. For example, the Return on Assets Managed for 45 stations ranged between about +27% and -16% (Bartle 2004). Longley (2000) found that the upper quartile of sheep producers achieved an average $53,000 cash surplus while the lower quartile returned a loss of $69,000. Clearly, there are some enterprises with good financial capacity and some with poor.

Attachment 7 – Conservation estate, off-reserve conservation and exclusions

Introduction

The last five years have seen enormous changes within the pilot region with respect to nature conservation. There has been a significant increases in land acquired for the conservation estate as a result of the Gascoyne-Murchison Strategy (GMS) as well as work towards off-reserve conservation through the Ecosystem Management Unit (EMU) project of the GMS and the purchase of several leases for conservation interests. Furthermore, a number of exclusions have been identified which will be removed from pastoral leasehold land in 2015.

The conservation estate and recent acquisitions

The proportion of each Interim Biogeographic Regionalisation for Australia (IBRA) sub-region protected at the level of IUCN I-IV and *Conservation and Land Management Act 1984 (CALM Act)* Section 33(2)[7] ranges from 3% to 24% (Table 7). None of the sub-regions have more than 26% of the vegetation associations that occur within the region protected at this level of classification (Rangelands NRM Co-ordinating Group 2005).

Table 7.1 For (IBRA) sub-regions in the (Australian Collaborative Rangeland Information System) ACRIS pilot project area - representation of IBRA sub-regions in IUCN I-IV and CALM Act Section 33(2) classification (see Footnote 7), number of Beard's vegetation associations occurring in the sub-region and percent of vegetation associations with greater than 15 per cent held within the above classified lands (after Rangelands NRM Co-ordinating Group 2005).

IBRA sub-region	Percent of sub-region in IUCN I-IV and CALM Act Section 33(2)	No. of Beard vegetation associations occurring in sub-region	Percent of vegetation associations with greater than 15% in IUCN I-IV and CALM Act Section 33(2)
Carnarvon 1	14	38	21
Carnarvon 2	9	82	15
Gascoyne 1	3	34	3
Gascoyne 2	10	26	15
Gascoyne 3	10	50	18
Geraldton Sandplain 1	24	32	22
Murchison 1	7	91	26
Murchison 2	4	58	19
Yalgoo	17	79	16

[7] IUCN I-IV refers to an international categorisation system for protected areas that the WA government has adopted for its reserve system (see http://www.iucn.org/themes/wcpa/wcpa/protectedareas.htm). CALM Act section 33(2) is used for recently purchased or acquired ex pastoral leases that have reverted back to UCL and are pending reservation as a protected area. Because they are pending reservation they are not covered under IUCN categories.

The capacity for nature conservation has been improved by acquisitions of pastoral land within the GMS area totalling 3.9 million ha between 1998 and 2004. This land was purchased on the commercial market by the Department of Conservation and Land Management (Figure 7.1) and doubles the number of vegetation associations represented in the region (Brandis 2004). The pre-existing conservation reserves of 1.4 million ha of land, plus the addition of the recently purchased 3.9 million ha brought the total area to 5.3 million ha, representing about 9% of the Strategy area. An additional 2.4 million ha is considered to be required to achieve a more comprehensive and adequate system (Brandis 2004).

To date, the recently acquired land has not been formally reserved, although it is currently managed by CALM for nature conservation. The improvement in the area that will be reserved varies across the region (Table 7.1), from 7.5 per cent in the Murchison IBRA to 32.6 per cent in the Geraldton Sandplain IBRA (Brandis 2004).

Table 7.1. Land in the conservation reserve system in 1998 and recent acquisitions for inclusion in the reserve system (adapted from Brandis 2004)

IBRA	1998 area (ha)	Percent of IBRA (1998)	2004 area (ha)	Percent of IBRA (2004)	Additional area required to reach 15% of IBRA
Gascoyne.	244,438	1.5	1,756,818	10.6	726,705
Carnarvon	265,908	3.5	871,810	11.6	253,646
Murchison	82,170	0.5	1,374,380	7.5	1,390,253
Yalgoo	486,136	12.7	988,947	25.6	_
Avon Wheatbelt	18,629	4.2	45,993	10.4	20,524
Geraldton Sandplain.	313,919	21.4	479,225	32.6	_
Total	**1,411,200**		**5,476,173**		**2,391,128**

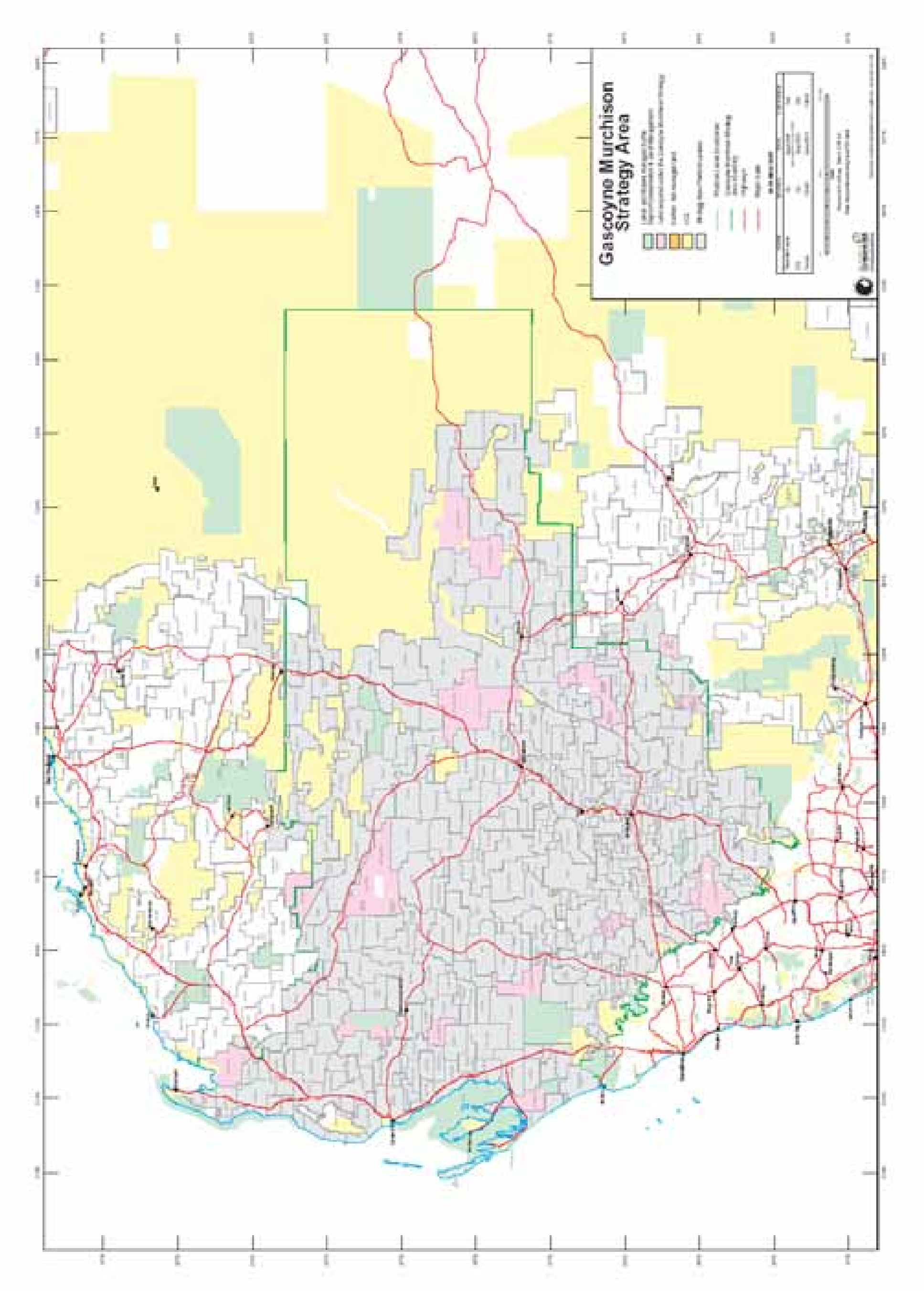
Most of the land acquired represents low pastoral productivity. Land of high pastoral productivity tends to be tightly held by the pastoral industry and therefore purchase opportunities are more limited (Brandis 2004). For the land where pastoral productivity had been formally assessed the acquisitions comprise 1.8 million ha of low value pastoral land, 1.2 million ha of moderate value pastoral land and 0.2 million ha of high value pastoral land.

There has been a large increase in the number of vegetation associations that will be represented within the conservation reserve system once the acquired areas are reserved. During the GMS the number of vegetation associations that will be represented increased from 74 (29 per cent of those mapped in the region) to more than 144. Whereas previously only about seven per cent of the vegetation associations had greater than 10 per cent of their area within the system, this has now increased to about 18 per cent (Brandis 2004).

About 60 vegetation associations considered to be restricted in distribution (i.e. having total area of less than 50,000 ha) will be included in the reserve system. The majority of these will have more than 10 per cent reserved (Brandis 2004).

About 110 (of 259) vegetation associations are still not represented, including about 80 associations with restricted distribution.

Figure 7.1. The location of land acquired by the Dept of Conservation and Land Management for conservation purposes as part of the Gascoyne-Murchison Strategy (taken from Brandis 2004).



Off-reserve conservation

Off reserve conservation in the region can be classified three ways. Pastoral leases now managed for conservation purposes, conservation on active pastoral leases and conservation as a default activity on unallocated (and generally unmanaged) Crown land. This section considers the first two.

Pastoral leases now managed for conservation purposes

In the Gascoyne Murchison region three pastoral leases have been bought since 2000 for the purposes of conservation.

Faure Island, in Shark Bay is now managed by the Australian Wildlife Conservancy (AWC) for the purposes of nature conservation. The Conservancy has released three species of nationally threatened mammals onto Faure Island (burrowing bettong, Shark Bay mouse and banded hare wallaby) and plans to release western barred bandicoots and greater stick nest rats in the near future (http://www.australianwildlife.org/faureisland.asp).

The AWC also manages Mt Gibson station (130,800 ha, now known as the Mt Gibson Conservancy) in the Yalgoo and Avon Wheatbelt IBRAs (http://www.australianwildlife.org/mtgibson.asp). Neighbouring White Wells station (68,600 ha, now known as the Charles Darwin Reserve) is managed by the Australian Bush Heritage Fund (http://www1.bushheritage.asn.au/). The Australian Bush Heritage Fund have also recently purchased Eurardy Station, just outside the pilot region area, in the Geraldton Sandplain2 sub-IBRA.

Mt Gibson Conservancy and the Charles Darwin Reserve now form part of an area close to 1,000,000 ha which is increasingly being managed for nature conservation both publicly and privately (Vital Options Consulting 2004; Peter Curry and Charlie Nicholson pers. comm.). The area sits across the junction of four bio-regions (Yalgoo, Avon, Coolgardie and Murchison) including the last intact part of the Avon bioregion. As well as the two pastoral leases now managed privately for conservation purposes, the area includes whole stations and part stations now managed by Department of Conservation and Land Management (CALM) existing nature reserves, timber reserves and Unallocated Crown Land as well as Ninghan station owned and managed by indigenous people. There are reported to be 730 species of flowering plants plus lichens and mosses on Ninghan, potentially giving it the longest plant list of any pastoral lease in Western Australia (Department of the Environment and Heritage 2005).

Conservation on active pastoral leases

A number of pastoral lessees actively manage for nature conservation on all or part of their leases while at the same time running commercial livestock grazing enterprises. Sometimes this management is active, such as excluding grazing from a particular area or actively protecting a particular habitat or species. Other times the management is passive, such as simply choosing not to develop (i.e. provide permanent water) to areas that are water remote, and therefore not grazed or only lightly grazed by all large herbivores. However, it is difficult to quantify this kind of private management on leasehold land.

The Ecosystem Management Unit (EMU) project of the GMS was designed to improve (amongst other things) off reserve conservation in the region (Pringle 2002). The project aimed to introduce pastoralists to the ecological management of landscapes, by recognising landscape and habitat patterns and processes (Tinley and Pringle 2002). By working closely with pastoralists the EMU project also sought to help pastoralists develop ways of managing biodiversity on their leases, without necessarily fencing them off.

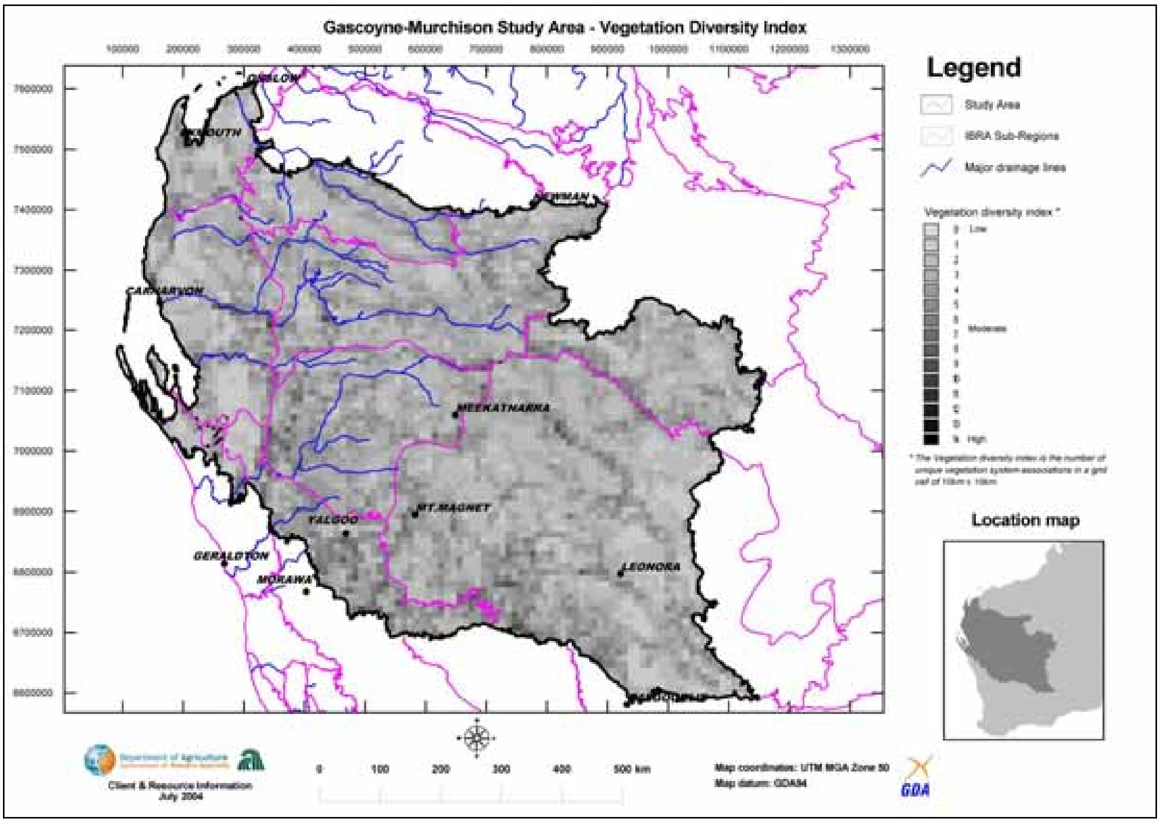
The EMU process engaged pastoralists on about 63 pastoral businesses over an area of about 15 million ha, predominantly in the pilot region. This included work with nine Land Conservation Districts. It helped put in place such activities as an Indigenous Protected Area, active pastoralist management of nationally listed wetlands, feral goat control to protect a habitat with threatened flora and other examples of active management of rare flora and the protection and restoration of landscapes not in the reserve system.

The EMU project also helped the local community develop catchment, riparian and floodplain management and restoration projects, many within landscapes not protected within the formal reserve system. The project also provided training to reserve managers, particularly in relation to the recently acquired leases, and to staff developing the Natural Resource Management regional strategy.

An evaluation of the EMU project (Braddick 2005) found that 20 per cent of land managers involved in the EMU process (the evaluation sampled 51 of 63 managers) had conserved or protected areas of land or specific plants as a result of the EMU process. There were 13 biodiversity projects implemented. Three of these were for specific plant species, one for wetland/lake systems, three for ‘land important for biodiversity’, one because of the confluence of land types, four to protect river systems and floodplains and one to protect coastal dunes. Note that these projects were instigated and implemented by pastoral lessees and do not reside on any formal register of protected areas.

One of the tools the EMU project produced to help guide investment decisions and to target off-reserve conservation efforts was a summary of areas where multiple vegetation associations could be found within relatively small areas (10 km x 10 km grid cells). The resultant index (vegetation diversity index) was defined as the number of unique vegetation system-associations within each grid cell (Figure 7.2). About two-thirds of the leases (including those whole or part leases acquired by CALM) in the ACRIS pilot project area have at least one grid cell containing four, five or six vegetation associations (Table 7.2).

Figure 7.2. Vegetation diversity index for the ACRIS pilot project region



Whole leases acquired by CALM tended to reflect lower values for the vegetation diversity index, suggesting that purchases were determined by other values (Table 7.2). However, the part leases acquired by CALM tended to have higher vegetation diversity. Taken together, it is clear that there remains a substantial role for off-reserve conservation, given that many leases with high vegetation diversity are not represented in the conservation reserve system.

Table 7.2. Maximum vegetation diversity index by pastoral lease. * Data for one lease not available. # Data for one lease not available.

Maximum vegetation diversity index on the lease	Number of leases	Number of whole leases purchased by CALM*	Number of part leases purchased by CALM#
2	7	0	0
3	21	0	1
4	57	6	2
5	76	3	3
6	74	1	4
7	29	2	2
8	24	3	4
9	11	1	1
10	5	0	1
11	1	1	0
12	1	0	0

Exclusions in 2015

About two million ha of the pastoral estate in Western Australia has been nominated for exclusion for 'public purposes' in 2015 under the Land Administration Act [1997]. Submissions for exclusion have been tabled for 97 of the state's 527 pastoral leases. 'Public purposes' include townsite expansion, expansion of horticultural precincts, protection of aboriginal sites and recreation and tourism. However, a significant number of proposals have been received as part of CALM's program to build a comprehensive, adequate and representative reserve system. Background on the exclusion process can be found at

http://www.dpi.wa.gov.au/pastoral/process.html .

The full list of exclusions can be found at http://www.dpi.wa.gov.au/pastoral/proposedexl.html

Attachment 8 – Lease sales and change in land values

Average land values, either as price paid per hectare or price paid per unit of carrying capacity (dollars/Dry Sheep Equivalent – DSE) remained relatively constant between 1998 and 2003 (Figure 8.1). Prices in 1997 were substantially lower than this steady period and prices in 2004 substantially higher. However, note that the sample size in 1997 was only four. Sales data for this summary were obtained from the Pastoral Lands Board while lease area and potential carrying capacity data were obtained from the Department of Agriculture.

The information contained in this section should be viewed with some caution since:

1. Sample size in some years was small and the range large, which has the potential to skew the average. However, both mean and median are reported as well as the range (although some outliers are excluded for privacy reasons).
2. All sales were included as reported, although terms of sale varied with respect to whether livestock, plant and equipment were included. That is, some stations were sold 'bare' and others were sold with stock and equipment, however it was not possible to differentiate the dollar breakdowns from the data provided.
3. Judgements were made by the author which excluded a number of sales from the analysis for the following reasons,
   - where the sale or transfer appeared to be internal, within company or family structures, or were for shares of the lease, or were between the Indigenous Land Corporation and indigenous owners, or were distributions based on the terms of a will, in which case the prices paid did not necessarily reflect market value and in some cases the transfers were made at nil price (n = 41)
   - where the price paid was excessive, typically because the station had some special feature which meant that its price did not represent the land value and would therefore unduly skew the average for that year (n = 4)
   - where part of the lease was sold as part of a restructuring arrangement, in which case it was not possible to determine the value at a whole of lease scale (n = approx. 21).
4. The carrying capacity estimates used were based on the assumption that the entire lease was in good range condition and all parts of the lease were within grazing radius of water. This figure, called the Potential Carrying Capacity, is nominal only and does not necessarily reflect the year-in-year-out carrying capacity of the lease for two reasons. Firstly, parts of the lease may be degraded and therefore have a lower carrying capacity. Secondly, parts of the lease may be beyond grazing radius of permanent water, i.e. infrastructure development may not be sufficient to carry the potential number of livestock.

The following summarises the lease sales between 1997 and 2004. There were 295 leases within the pilot region (note that this differs slightly from the 292 mentioned elsewhere).

1. There were 105 sales, some of which involved multiple leases.
2. There were 111 leases sold in these 105 sales.
3. Twelve leases sold twice and one lease sold three times.
4. CALM bought 18 whole leases (and 19 part leases not considered here).
5. The Indigenous Land Corporation bought four leases.
6. Private conservation interests bought three leases.

Excluding the internal transfers and sales of part leases detailed above, nearly 40 per cent of leases in the pilot region changed hands over the eight year period 1997–2004, i.e. an average of about five per cent per year. This is a similar average annual rate to that estimated by URS for the Gascoyne-Murchison Strategy region between 1999 and 2004 (URS 2004).

As part of the acquisition program within the Gascoyne-Murchison Strategy, the Department of Conservation and Land Management (CALM) bought 18 whole leases between December 1998 and June 2004. This represented about 21 per cent of the leases sold during this period and the acquisition program clearly boosted the total number of leases sold in 1999 and 2000, when CALM bought 12 of its 18 leases. The increased demand did not seem to increase land values (Figure 8.1).

Seven very productive leases (greater than about 10 DSE/km^2) attracted some of the highest prices per hectare and per DSE (Figure 8.2). Raw data has not been presented for privacy reasons but it is clear that for these productive leases, the price paid increased as the average lease productivity increased. These leases were obviously highly sought after and of limited availability, making up only seven per cent of sales between 1997 and 2004.

Four sales (three leases) changed hands for well in excess of their pastoral value and these have not been included in either of the figures. While this number of sales is low, there is also evidence that the practice of paying for non-pastoral value is more widespread. If pastoral value alone was the determinant of price paid then it could be expected that the price paid per hectare and the price paid per DSE would increase as the average productivity of the lease increased. That is, leases with high average carrying capacities should command higher prices per ha or per DSE, while leases with low average carrying capacity would fetch only low prices.

However, the data do not show this relationship (Figure 8.2). Leases with a low to moderate average productivity (3.5 to 10 DSE/km^2) fetched both low and high prices per hectare and per DSE. This suggests that pastoral value was not always a key determinant of price paid on less productive leases. The URS findings that the proportion of non-pastoral income tended to be higher on less productive leases and that their location coincided with increased opportunities for off-station income due to mining opportunities (URS 2004) suggests that at least some of these less productive leases are being valued in excess of their pastoral value because of other criteria. It is also clear from the sales data that mining companies bought some of these leases and in these cases pastoral income is of small consequence compared with the benefits of owning the lease.

Note that an alternative explanation is that the theoretical relationship between price and productivity may not hold true due to some of the caveats raised above (e.g. sale prices used may or may not include stock and equipment) and because other factors such as distance to towns, abbatoirs or ports has a disproportionate impact on prices paid for pastoral leases. Another important determinant of price is the quality and extent of infrastructure, such as fences and watering points, so that a lease of low productivity but good infrastructure might command a higher price (per hectare or per DSE) than a lease of higher productivity but poor infrastructure.

Figure 8.1. Summary of lease sales in the Gascoyne-Murchison pilot region between 1997 and 2004. The maximum and minimum values for 1997 and 2003 are not shown due to small sample size and reasons of privacy.

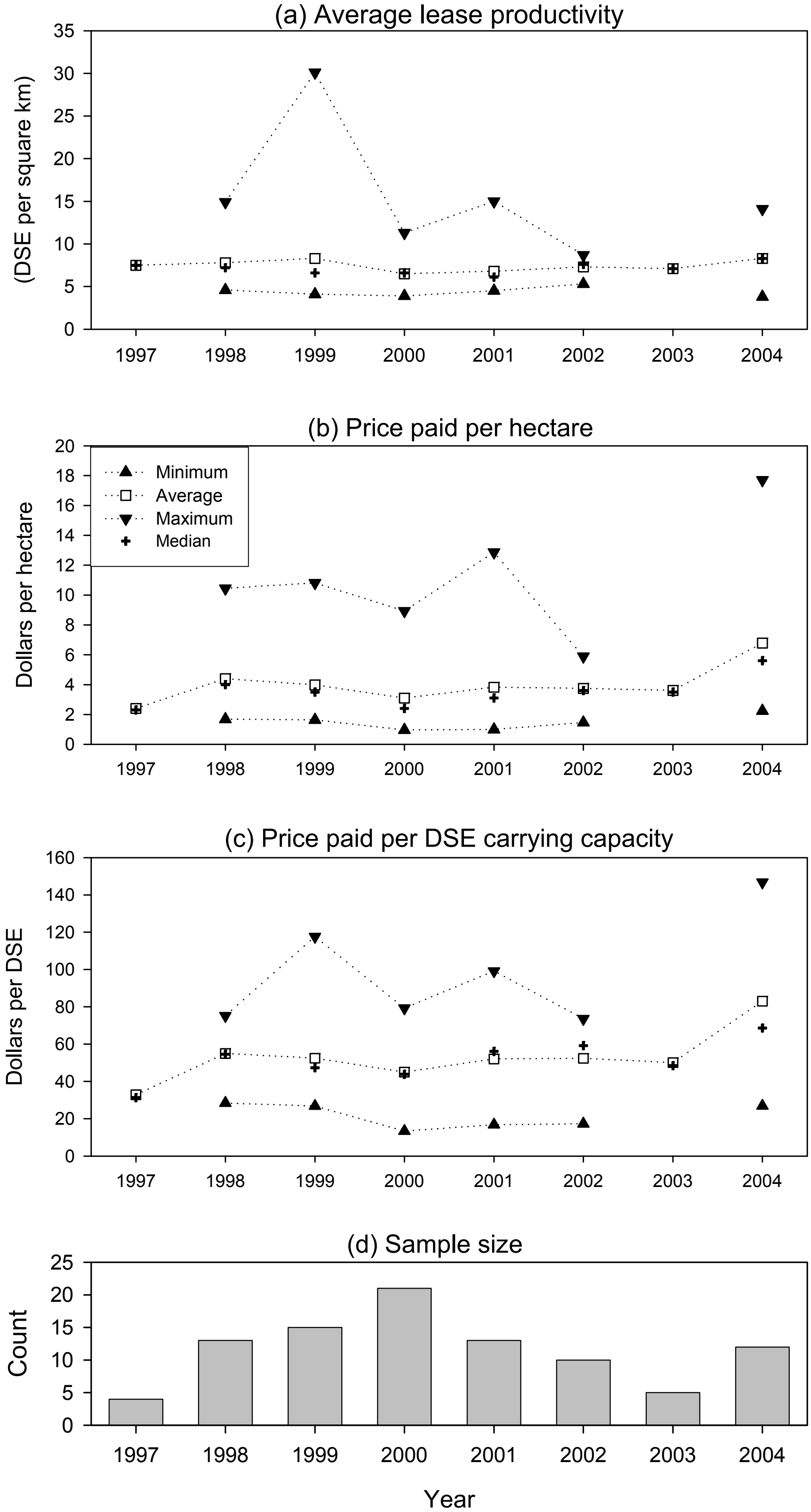
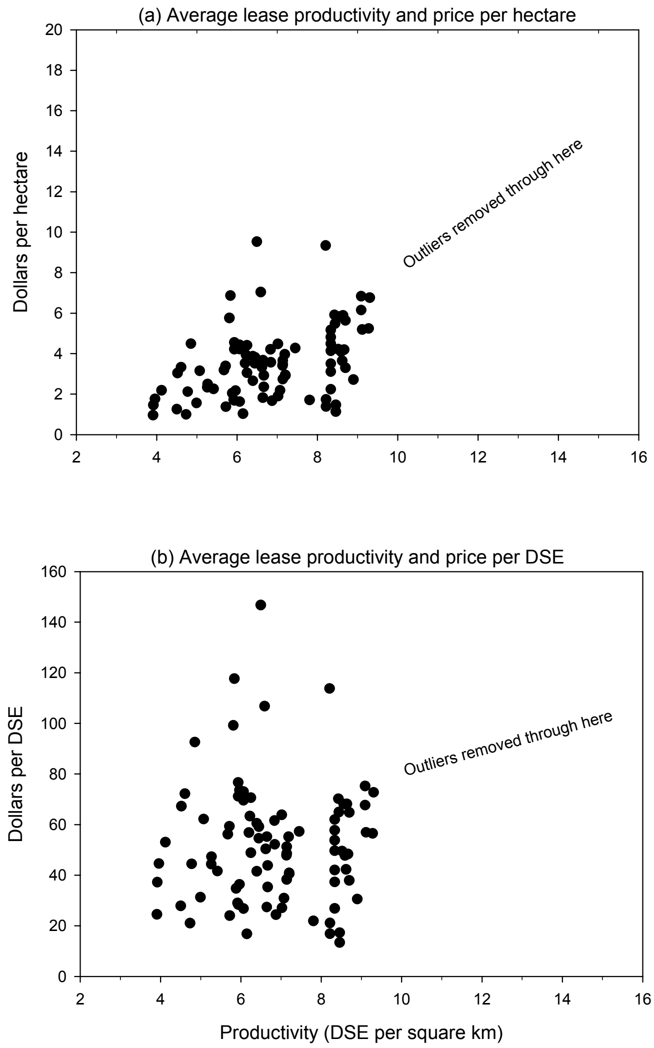


Figure 8.2. The relationship between average lease productivity (Potential Carrying Capacity divided by the area) and the prices paid. Several outliers have been removed for privacy reasons.



Attachment 9 – Biodiversity assets in the pilot region

Biodiversity Summary

The principle concept explored in this section is to develop an understanding of status and change of biodiversity in the Gascoyne-Murchison region. The biodiversity assets examined here relate specifically to mid-order biodiversity values - species and communities; other biodiversity values and threats (e.g. changes in landscape function) are included in other sections.

The data below are summarised from the biodiversity audit of May and McKenzie (2003) and relate specifically to threatened and priority species and communities, riparian zones and wetlands and river systems. Definitions of the categories used to describe the status of communities and species are found in Table 9.20.

Communities

The communities included in this analysis are those that are considered important for biodiversity (wetlands, riparian vegetation and rivers) and those that retain specific values (threatened ecological and other communities at risk).

Status

Within the study area there are:

- Eighteen wetlands of national significance. One of these (Lake MacLeod) is considered a biological refuge (Morton et al. 1995).
- Eighteen wetlands of sub-regional significance.
- Thirteen riparian zones are considered in the biodiversity audit.
- There is only one endorsed Threatened Ecological Community but another 112 ecosystems considered at risk within the Gascoyne-Murchison region.

Change

For all these community types combined, there is a general pattern of decline and similarity in threatening processes.

- Nearly one-half (47 per cent) are in fair or less condition, with 14 per cent considered degraded.
- The condition of only two per cent are considered improving, 41 per cent are declining.
- Grazing pressure (in 30 per cent of instances) and feral animals (31 per cent) are considered important for the present status and trend in these communities.

Vertebrate Species

Status

- Regionally, four mammal species are mainland extinct now retaining only island populations. Another species (the bilby, *Macrotis lagotis*) is regionally extinct from one subregion (MUR1).
- There is only one instance of improvement in trend of a threatened or priority vertebrate species: the mallee fowl (*Leipoa ocellata*) from CAR2.
- Of the 225 birds in the region, there are three threatened (one Critically Endangered, one Endangered, one Vulnerable) and 11 priority species (one P3, 10 P4). From the literature 38 (17 per cent) other bird species within the region are declining and 51 species are increasing.

Change

Some general patterns can be developed for each vertebrate group:

- No mammals (that are declared rare, or threatened or priority listed) are in better than fair condition, 54 per cent are, at best, declining. Feral animals (42 per cent) and changed fire regimes (33 per cent) account for most of these patterns.
- The majority (52 per cent) of the birds are in fair but declining (57 per cent) condition, with grazing (29 per cent) and feral animals (25 per cent) responsible.
- Sixty-six precent of the reptiles are in fair or worse condition, most are declining (54 per cent). Feral animals (37 per cent) and grazing pressure (26 per cent) being largely responsible for these patterns.

Flora

Of the 3,557 vascular plant species in the study area, 333 are considered threatened or conservation priority one to four taxa. One hundred and thirty-eight of these species (those either threatened or priority one and two) were used to develop an understanding of condition and status.

- The condition of 59 per cent of threatened or priority species is unknown, but 18 per cent are in good condition (the rest are, generally, in fair condition 22 per cent).
- The trend in this condition is largely unknown (70 per cent), 17 per cent are in decline, and 11 per cent are static.
- Grazing pressure (26 per cent), feral animals (25 per cent) and exotic weeds and changes in fire regimes (both 20 per cent) are driving these trends.

There are 341 species of the Gascoyne-Murchison with a grazing response category (derived from the The Western Australian Rangeland Monitoring System (WARMS) data): 126 Decreasers, 38 Increasers and 177 intermediate. Of the species of conservation risk two are grazing Decreasers.

There are 189 naturalised plant species in the Gascoyne-Murchison area. Of these 156 species are considered environmental weeds by Keighery and Longman (2004). Nine of these environmental weeds have a grazing response category: five are Decreasers, four Increaser.

Data Sets and Analysis

The regions considered for these analyses are the 9 Interim Biogeographic Regionalisation for Australia (IBRA) sub-regions that are included in the Gascoyne-Murchison namely: CAR1, CAR2, GAS1, GAS2, GAS3, MUR1, MUR2, GS1 and YAL. Generally, this collation is of onshore values and ecosystems except those in the inter-tidal areas. However, data on threatened and priority flora may include island species.

Threatened species and community biodiversity assets, condition, trend and threats were extracted from the biodiversity audit (May and McKenzie, 2003). May and McKenzie (2003) collates biodiversity information at the sub-IBRA level.

Within the audit there are 12 categories of threat, within each of these categories there are subcategories specifying the specific threat. For instance, feral animals may be divided into specific animals (e.g. camels, rabbits etc); in our summary these sub-categories are ignored and categories were often combined for ease of interpretation. Each community/species may have numerous threatening processes operative. In these instances all threatening processes were collated, thus there are more threatening processes than listed communities or species.

Some fauna while not presently listed as threatened on Commonwealth or Western Australian lists, may be undergoing significant declines in density or range (see Recher 1999). To capture this information a regional species list was compared to the literature outlining these species. For instance, while some Gascoyne-Murchison bird species are not considered at risk regionally these same species are considered in decline nationally.

Community Level

Threatened and Priority Ecological Communities

There are two types of communities used in these analyses. The first are those designated Threatened Ecological Communities (TECs). These have Ministerial endorsement as a TEC and are listed on the Western Australian Threatened Species and Communities Unit, Department of Conservation and Land Management's (CALM) TEC Database. The second type of community is those listed as Priority Communities. These, for several reasons (principally lack of survey data) do not qualify as TECs.

TECs and Priority communities were extracted from the Western Australian Threatened Species and Communities Unit, CALM's TEC Database, current March 2004. These were compared with the lists of TECs and other ecosystems at risk in May and McKenzie (2003), to maintain data currency.

Data on threats, condition, and active threatening processes for these communities were taken from May and McKenzie (2003).

Wetlands and Riparian Systems

These were extracted from the May and McKenzie (2003). For values of wetlands of national significance see http://www.deh.gov.au/water/wetlands.

Species level

Condition, trend and threatening processes for both flora and fauna were summarised from May and McKenzie (2003). Many species were found in more than one of the nine sub-IBRA regions that defined the study area. To develop an understanding of these species across their range condition, trend and threatening processes were collated for all occurrences of these species across the region.

Fauna

Marine and island species were not included in this analysis. It is assumed that all crustaceans from the area in the biodiversity audit are mainland species and are thus included. Conservation categories are from the *Wildlife Conservation (Specially Protected Fauna) Notice 2003*.

Threatened fauna data was derived from May and McKenzie (2003) and from the Priority Fauna Database held by CALM Wildlife Conservation Section in July 2004. Species from the latter were only included if there were records with a high certainty of correct identification and from living species (i.e. bone records excluded).

A bird species list for the area was derived from:

i. The WA Museum Faunabase, in late July 2004. This system does not allow for exact regions to be intersected, thus the fauna list was taken from two quadrats within the greater Gascoyne-Murchison area (23.48° S, 113.60° E/ 25.36° S, 119.94° E and 25.36 S, 116.63° E/ 29.40°S, 122.36°E).
ii. May and McKenzie (2003).
iii. Johnstone *et al.* (1999).
iv. The Priority Fauna Database held by CALM Wildlife Conservation Section in July 2004.

To determine bird species that may be undergoing significant change (but not identified as Threatened or Priority species) the regional bird species list was compared to two papers. James *et al.* (1999) summarises birds that have declined due to grazing and the provision of waterpoints. Johnstone *et al.* (2003) presented a list of species in the Carnarvon Basin that had changed in density or distribution since 1951.

We developed these lists from species thus subspecies information may have been integrated. For example, information on habitat and range from James *et al.* (1999) for the Mallee Ringneck (*Barnardius zonarius barnardi*) was used for the regional subspecies (*B. z. zonarius*).

Flora

The species list for the Gascoyne-Murchison region was extracted from the State Herbarium Database, June 2004. A weed list was derived from this data; environmental weeds were identified from this list from Keighery and Longman

(2004). The determination of status, trend and threatening processes was done by collating threatened and priority flora from May and McKenzie (2003), this list is of threatened and priority one and two species only.

A list of grazing Increaser and Decreaser plant species for the area was derived from the WARMS database. These classifications are based on expert knowledge. For some species, response categories vary across the region or within different habitats. For example, some species act as Decreasers when found in a certain habitat and as intermediates when found in other habitats. In these cases, the species was categorised as a Decreaser. The WARMS grazing response species records were reduced to those species only found in the study area. Some remaining taxa (11 species) had several records with contradictory response groups, these were deleted from further analysis.

Feral animals

Data on other grazers (camels, goats, emus, donkeys) was sourced from unpublished papers by Andrew Woolnough (Department of Agriculture, Western Australia) and Peter Mawson (CALM).

Results

The Gascoyne-Murchison area contains significant biodiversity value including, due to high levels of plant endemicity, two national biodiversity hotspot areas. However, developing an understanding of change and status in biodiversity was constrained by having little historical or contemporary data on most species and communities. In these analyses we used generally-threatened and priority species and communities as these have been more fully examined. From these we explored the patterns in status and condition by examining reported trends and the processes driving these changes.

Communities

The communities considered in this analysis are those that are considered important for biodiversity (wetlands, riparian vegetation and rivers) and those that retain specific values (threatened ecological and other communities at risk).

Within the study area there are:

- Eighteen wetlands of national significance (Table 9.12). One of these (Lake MacLeod) is considered a biological refuge (Morton *et al.* 1995).
- Eighteen wetlands of sub-regional significance (Table 9.3).
- Thirteen riparian zones considered in the biodiversity audit (Table 9.14).
- There is only one endorsed Threatened Ecological Communities and another 112 ecosystems considered at risk within the Gascoyne-Murchison region (Table 9.15).

For all these community types combined, there is a general pattern of decline and similarity in threatening processes. Nearly one-half (47 per cent) are in fair or less condition, with 14 per cent considered degraded (Table 9.1). The condition of only two per cent are considered improving, 41 per cent are declining (Table 9.2). Grazing pressure (in 30 per cent of instances) and feral animals (31 per cent) are considered important for the present status and trend in these communities (Table 9.3).

Wetlands

Fifty percent of the wetlands of national significance are considered in either good or good to near pristine condition (Table 9.1). In 61 per cent of these wetlands the condition trend is considered static, but the trend of 28 per cent is unknown (Table 9.2). The dominant deleterious processes driving the decline in condition and trend are grazing pressure (36 per cent of cases) and feral animals (33 per cent of cases), Table 9.3.

Sixty-seven percent of the 13 wetlands of sub-regional significance are in either near pristine or good condition (Table 9.1). In contrast, 22 per cent are considered degraded. But 61 per cent of them are in declining trend (Table 9.2). The decline in the condition of these wetlands is mainly due to feral animals (34 per cent) or grazing pressure (24 per cent), Table 9.3.

Rivers and Riparian Areas

There are 13 riparian zones of the Gascoyne-Murchison considered in the biodiversity audit. Sixty-two percent are considered degraded (Table 9.1). Eighty-five percent (11) are declining (Table 9.2). The main threats to these systems are grazing pressure, feral animals, exotic weeds and changes in hydrology (Table 9.3). The river systems that support these communities (the Gascoyne - Murchison and Lyndon-Minilya systems) are considered degraded (WRC 1997, Halse *et al.* 2001).

Threatened Ecological Communities (TEC)

There is only one endorsed TEC and another 112 ecosystems considered at risk within the Gascoyne-Murchison region (Table 9.15). Inclusion of a community as threatened or at risk does not necessarily imply that the community has been reduced in distribution or extent. At the very least these communities retain unique values and are under threat. Of the communities so designated, only 27 per cent of these are considered in good to near pristine condition (Table 9.1). Forty percent are either declining or rapidly declining (Table 9.2). Grazing pressure and feral animals are largely responsible for the present condition and trend (Table 9.3).

Table 9.1. The condition of wetlands of national significance and sub-regional significance, riparian zone vegetation and Threatened and Priority Ecological Communities of the Gascoyne-Murchison Region. Summarised from the biodiversity audit (May and McKenzie, 2003).

	Wetlands of National Significance		Wetlands of Sub-Regional Significance		Riparian Zone Vegetation		Threatened and Priority Ecological Communities		Totals
	Number	%	Number	%	Number	%	Number	%	% of all data
Near Pristine			2	11			2	2	2
Good to Near Pristine	2	11					2	2	2
Good	7	39	10	56			26	23	27
Fair to Good	3	17					17	15	12
Fair	6	33	2	11	5	38	37	33	31
Degraded to Good							1	1	<1
Degraded to Fair							4	4	2
Degraded			4	22	8	62	11	10	14
Unknown							8	6	4
Variable							5	4	3
Total	18		18		13		113		

Table 9.2. The trend in condition of wetlands of national significance and sub-regional significance, riparian zone vegetation and Threatened and Priority Ecological Communities of the Gascoyne-Murchison Region. Summarised from the biodiversity audit (May and McKenzie, 2003).

	Wetlands of National Significance		Wetlands of Sub-Regional Significance		Riparian Zone Vegetation		Threatened and Priority Ecological Communities		Totals
	Number	%	Number	%	Number	%	Number	%	% of all data
Rapidly declining	1	5					3	3	2
Declining			11	61	11	85	40	36	39
Declining to static	1	5			2	15	2	2	3
Static	11	61	5	28			27	24	27
Improving							4	4	2
Unknown	5	28	2	11			37	32	27
Total	18		18		13		113		

Table 9.3. The threatening processes considered important for the wetlands of national significance and sub-regional significance, riparian zone vegetation and Threatened and Priority Ecological Communities of the Gascoyne-Murchison Region. Summarised from the biodiversity audit (May and McKenzie, 2003).

	Wetlands of National Significance		Wetlands of Sub-Regional Significance		Riparian Zone Vegetation		Threatened and Priority Ecological Communities		Totals
	Number	%	Number	%	Number	%	Number	%	% of all data
Habitat fragmentation and Vegetation clearing					2	4	7	3	2
Grazing pressure	13	36	10	24	13	24	80	31	30
Feral animals	12	33	14	34	13	24	81	31	31
Exotic weeds	2	6	7	17	13	24	5	2	7
Changed fire regimes					6	11	44	17	13
Salinity	1	3					4	2	1
Changed hydrology			6	15	8	15	3	1	4
Development, mining and inappropriate tourism	4	11					15	6	2
Pollution	3	8					1	<1	1
Visitor impacts			3	7					1
Fishing	1	3					2	1	1
No known threatening processes			1	2			1	<1	<1
Erosion							16	6	4
Total	36		41		55		257		100

Species

Fauna

The regional vertebrate fauna is in general decline with feral animals and grazing pressure largely responsible for these patterns. This is in agreement with other areas of rangelands. Regionally, four mammal species (*Lagostrophus fasciatus*, *Bettongia lesueur lesueur*, *Isoodon auratus auratus* and *Pseudomys fieldi*) are mainland extinct now retaining only island populations. Another species, the bilby (*Macrotis lagotis*) is regionally extinct from one subregion (MUR1). There is only one instance of improvement in trend of a threatened or priority vertebrate species: the mallee fowl (*Leipoa ocellata*) from CAR2.

Table 9.18 shows the threatened and priority fish, mammals and reptiles for the study region. Table 9.17 shows the complete derived bird list for the study area.

Of the 20 threatened and priority 1 and 2 extant mainland vertebrate species only 15 per cent are considered in good condition, 29 per cent are degraded and 48 per cent are considered fair (Table 9.4). Only four per cent of these species are considered improving whereas the trend for 52 per cent are declining or rapidly declining (Table 9.55). For all the vertebrate groups combined, feral animals are considered an important threatening process in 29 per cent of cases; grazing pressure (22 per cent) and changed fire regimes (20 per cent) (Table 9.6).

Threatening processes for the vertebrates are variable across the groups (Table 9.6). Foxes and cats are the most potent threatening process for the mammals and reptiles with grazing pressure the most important for the birds.

Some general patterns can be developed for each vertebrate group:

- No mammals (that are declared rare, or threatened or priority listed) are in better than fair condition, 54 per cent are, at best, declining (Table 9.5); feral animals (42 per cent) and changed fire regimes (33 per cent) account for most of these patterns (Table 9.6).
- The majority (52 per cent) of the birds (that are declared rare, or threatened or priority listed) are in fair (Table 9.4) but declining (57 per cent) condition (Table 9.5), with grazing (29 per cent) and feral animals (25 per cent) responsible (Table 9.6).
- Sixty-six precent of the reptiles (that are declared rare, or threatened or priority listed) are in fair or worse condition (Table 9.4), most are declining (54 per cent; Table 9.5); feral animals (37 per cent) and grazing pressure (26 per cent) being largely responsible for these patterns (Table 9.6).

Of the 225 bird species in the region, there are three threatened (one Critically Endangered, one Endangered, one Vulnerable), eleven priority (one P3, 10 P4) and two Specially Protected species (Table 9.16). May and McKenzie (2003) identify grazing pressure as a threatening process in 29 per cent of these threatened and listed species (Table 9.6). The summary presented in James *et al.* (1999) implicated grazing (and/or provision of water) as the threatening process in nine of these species (Table 9.17). Another regional species (the scarlet-chested Parrot, *Neophema splendida*), while considered to be extinct in many areas (James et al. 1999) is not on state threatened lists.

According to the lists provided in James et al. (1999), another 15 unlisted species are thought to have had their range or abundance lowered by pastoralism (Table 9.17). Four of the local bird species are reported as increasing in some areas and decreasing in others, while 40 others have benefited from pastoralism and water provision.

From these data, nine of the 16 listed and specially protected species have declined due to pastoral activity and another 15 are decreasing because of it.

Analysing bird data from 1951 to present for 165 regional species, Johnstone et al. (2000) determined changes in distribution and density for 163 species. While they did not allocate causation for decline they found that 24 species had decreased, 22 have increased, and changes in 116 had not been detectable. Only 5 regionally threatened and priority species were examined in their data, they found declines in two of them (Australian bustard and bush stone-curlew), while for three other species (thick-billed grasswren, rufous fieldwren and white-browed babbler) there was no detectable change.

If we assume that Johnstone et al. (2000*)* gives regional Decreasers and that James et al. identifies other species not detected by Johnstone *et al.* as changing we can develop a measure of change and potential changes within the region. Not including species threatened, priority or specially protected, or those species that James et al.

consider variable (i.e. at the continental scale have increased in some areas and decreased in others) 38 bird species within the region are declining and 51 species are increasing (Table 9.17).

There are 20 threatened or priority species of invertebrate fauna within the GM region, each has a single occurrence in May and McKenzie (2003). One of these species is Critically Endangered, 16 are considered Endangered, and three are Vulnerable (Table 9.19). The condition of all these species is good, but the trend of these species is unknown. Pollution is considered a threatening process in all these species, while mining is a threat for 19 of them (data not shown).

Table 9.4. The condition of the Threatened and Priority vertebrate fauna of the Gascoyne-Murchison region, summarised from May and McKenzie (2003).

	Mammals		Birds		Reptiles		Fish		Totals %
	Number	%	Number	%	Number	%	Number	%	% of all data
Degraded	6	46	5	22	2	22	1	33	29
Fair	7	54	12	52	4	44		0	48
Fair to Good			1	4	1	11		0	4
Good			3	13	2	22	2	67	15
Unknown			2	9				0	4
Totals	13		23		9		3		

Table 9.5. The trend in condition of the Threatened and Priority vertebrate fauna of the Gascoyne-Murchison region, summarised from May and McKenzie (2003).

	Mammals		Birds		Reptiles		Fish		Totals %
	Number	%	Number	%	Number	%	Number	%	% of all data
Possibly Regionally Extinct	1	8							2
Rapidly declining to declining	1	8			2	18			6
Declining	6	46	13	57	4	36			46
Declining to static	1	8							2
Static	1	8	5	22	4	36			20
Improving			1	4					4
Unknown	3	23	4	17	1	9	3	100	20
Total	13		23		11		3		50

Table 9.6. The threatening processes operating on the Threatened and Priority vertebrate fauna of the Gascoyne-Murchison. Summarised from May and McKenzie (2003)

	Mammals		Birds		Reptiles		Fish		Totals %
	Number	%	Number	%	Number	%	Number	%	% of all data
Feral animals (cats and/or foxes)	10	42	12	25	7	37			29
Feral animals (predators and herbivores)			3	6			3	38	6
Changed Fire Regimes	8	33	8	17	4	21			20
Grazing Pressure	2	8	14	29	5	26	1	13	22
Other Human Disturbances	2	8	2	4					4
Not Threatened	2	8							2
Increasing fragmentation, loss of remnants and lack of recruitment			9	19	3	16			12
Pollution							2	25	2
Mining							2	25	2
Totals	24		48		19		8	100	

Flora

Of the 3,557 vascular plant species in the study area, 333 are considered threatened or conservation priority 1 to 4 taxa. One hundred and thirty-eight of these species (those either threatened or priority 1 and 2) were used to develop an understanding of condition and status.

The condition of 59 per cent of threatened or priority species is unknown, but 18 per cent are in good condition (Table 9.7). The trend in this condition is largely unknown (70 per cent; Table 9.8), 17 per cent are in decline, and 11 per cent are static. Grazing pressure (26 per cent), feral animals (25 per cent) and exotic weeds and changes in fire regimes (both 20 per cent) are driving these trends (Table 9.9).

Table 9.7. Summary of the condition of Threatened and Priority 1 and 2 flora of the Gascoyne-Murchison. From May and McKenzie (2003).

	Number	%
Degraded	3	2
Fair	34	22
Good	28	18
Unknown	92	59
Total	157	

Table 9.8. Summary of the trend in condition of Threatened and Priority 1 and 2 flora of the Gascoyne-Murchison. From May and McKenzie (2003).

	Number	%
Declining	27	17
Declining to static	2	1
Static	18	11
Unknown	110	70
Total	157	

Table 9.9. The threatening processes operating on the Threatened and Priority flora of the Gascoyne-Murchison. Summarised from May and McKenzie (2003).

	Number	%
Changed fire regimes	102	20
Changed hydrology	7	1
Exotic weeds	104	20
Feral animals	129	25
Grazing pressure	136	26
Increasing fragmentation	19	4
Mining	2	<1
Natural processes such as cyclones and fire	1	<1
Vegetation clearing	11	2
Salinity	5	1
Pollution	1	<1
Other	1	<1
Unknown threatening processes	1	<1
Total	519	

There are 341 species in the Gascoyne-Murchison with a grazing response category: 126 Decreasers, 38 Increasers and 177 intermediate. Of the species of conservation risk two are grazing Decreasers and a further six have not been determined (Table 9.10).

Table 9.10. The grazing Increaser and Decreaser threatened and priority species of the Gascoyne-Murchison. Grazing response category was determined from the WARMS database (see methods).

Name	Common Name	Conservation Code	Grazing Response Category
Eucalyptus beardiana		Rare	Intermediate
Ptilotus lazaridis	Saline mulla mulla	P1	Decreaser
Eucalyptus jutsonii		P2	Intermediate
Ptilotus beardii	Low mulla mulla	P3	Decreaser
Grevillea annulifera		P3	Intermediate
Grevillea rogersoniana	Rogersons grevillea	P3	Intermediate
Acacia drepanophylla	Hamelin wattle	P3	Intermediate
Hemigenia tysonii		P3	Intermediate

There are 189 naturalised plants in the GM area. Of these 156 species are considered environmental weeds by Keighery and Longman (2004). Nine of these environmental weeds have a grazing response category: five are decreasers, four increasers (Table 9.11).

Table 9.11. The weeds of the Gascoyne-Murchison that have a grazing response category (see text)

Name	Common Name	Grazing Response Category
Cenchrus ciliaris	Buffel grass	Decreaser
Cenchrus setigerus	Birdwood grass	Decreaser
Aerva javanica	Kapok bush	Decreaser
Medicago polymorpha	Medic	Decreaser
Emex australis	Double gee, devil's curse	Increaser
Malvastrum americanum		Increaser
Nicotiana glauca	Poison tobacco, native tobacco	Increaser

Overview

There have been substantial changes in the biodiversity within the Gascoyne-Murchison. Typically, these changes are declines in native species and community condition through feral predators, grazing pressure and changes in fire regimes. There is variation in the drivers of changes between groups. At the species level, mammal decline is largely due to feral predators (above and Burbidge and McKenzie, 1989); bird declines appear to relate to changes in vegetation structure due to changes in fire regimes and grazing pressure (above and Recher and Lim, 1990).

Reduction of these threatening processes is critical to retain and improve the status of the biodiversity values identified. There are considerable challenges to reduce the impacts of feral predators, but some opportunity in reducing the effects of changes in vegetation structure through overgrazing of stock, feral herbivores (e.g. goats) and native species (kangaroos). While there has been a considerable historical impact; a substantial amount of land has been recently acquired for the conservation estate. On these properties at least (due to closing of waterpoints) grazing impacts should be reduced. As it is unlikely that the conservation estate will ever be able to fulfil the full suite of regional conservation objectives, a greater uptake of ecological understanding is critical.

Table 9.12. The wetlands of national significance of the Gascoyne-Murchison Region. Extracted from the biodiversity audit (May and McKenzie, 2003).

Sub-IBRA	Name	Condition	Trend	Threatening Processes
CAR1	Cape Range subterranean waterways (includes Bundera sinkhole and other karst feature waterways)	Good	Static	Grazing pressure, Feral animals, Salinity, Pollution
CAR1	Exmouth Gulf East	Good	Static	Grazing pressure, Feral animals, Exotic Weeds
CAR2	McNeill Claypan	Fair	Rapidly declining	Grazing pressure, Development, Pollution
CAR2	East Shark Bay	Good to Near Pristine	Static	Fishing, Pollution
CAR2	Hamelin Pool	Good to Near Pristine	Static	Inappropriate tourism
CAR2	Lake MacLeod	Good	Static	Mining, Grazing pressure
GAS1	Kookhabinna Creek Gorges	Good	Static	Feral animals, Exotic weeds
GAS1	Yadjiyugga Claypan	Good	Static	Feral animals
GAS2	Windich Springs	Fair	Declining to static	Grazing pressure, Feral animals
GAS2	Lake Carnegie system	Good	Static	Grazing pressure
MUR1	Lake Marmion	Fair	Static	Grazing pressure
MUR1	Lake Ballar	Fair	Static	Grazing pressure, Feral animals
MUR1	Lake Barlee	Fair	Static	Grazing pressure, Feral animals
MUR2	Wooleen Lake	Fair to Good	Unknown	Grazing pressure, Feral animals
MUR2	Breberle Lake	Fair to Good	Unknown	Grazing pressure, Feral animals
MUR2	Anneen Lake	Fair to Good	Unknown	Grazing pressure, Feral animals, Mining
YAL	Thundelarra Lignum Swamp	Good	Unknown	Grazing pressure, Feral animals
YAL	Wagga Wagga Salt Lake	Fair	Unknown	Feral animals

Table 9.13. The wetlands of sub-regional significance of the Gascoyne-Murchison Region. Extracted from the biodiversity audit (May and McKenzie, 2003).

Sub-IBRA	Name	Condition	Trend	Threatening Processes
CAR1	Bay of Rest	Good	Static	No known threatening processes
CAR1	Ningaloo Reef	Good	Declining	Visitor impacts
CAR1	Mangrove Bay	Near Pristine	Static	Visitor impacts
CAR1	Yardie Creek	Good	Static	Visitor impacts, Grazing pressure, Feral animals
CAR2	Minilya River	Degraded	Declining	Changed hydrology, Exotic weeds, Grazing pressure, Feral animals
CAR2	Wooramel River	Degraded	Declining	Changed hydrology, Exotic weeds, Grazing pressure, Feral animals
CAR2	Gascoyne River	Degraded	Declining	Changed hydrology, Exotic weeds, Grazing pressure, Feral animals
GAS1	Major pools in Ashburton and Hardy Rivers	Degraded	Declining	Feral animals, Exotic weeds
GAS1	Minnie Spring	Fair	Declining	Feral animals, Exotic weeds
GAS1	Irragully Creek	Fair	Declining	Feral animals, Exotic weeds
GAS1	Calcrete aquifers of the Lyons River	Near Pristine	Static	Exotic weeds
GAS3	Mibbley Pool	Good	Declining	Grazing pressure, Feral animals
GAS3	Erong Springs	Good	Declining	Grazing pressure, Feral animals
GAS3	Edithana Pool	Good	Declining	Grazing pressure, Feral animals
GAS3	Cattle Pool	Good	Declining	Grazing pressure, Feral animals
MUR2	Mungawolagudgi Claypan (Muggon Station)	Good	Static	Feral animals, Changed hydrology
YAL	Lake Moore	Good	Unknown	
YAL	Lake Monger	Good	Unknown	Grazing pressure, Feral animals, Changed hydrology

Table 9.14. The riparian zone vegetation of the Gascoyne-Murchison Region. Extracted from the biodiversity audit (May and McKenzie, 2003).

sub-IBRA	Name	Condition	Trend	Threatening Processes
CAR1	Lyndon – Minilya Rivers	Degraded	Declining	Grazing pressure, Feral animals, Exotic weeds, Changed fire regimes
CAR1	Permanent and semi-permanent pools	Degraded	Declining	Grazing pressure, Feral animals, Exotic weeds
CAR2	Gascoyne River	Degraded	Declining	Grazing pressure, Feral animals, Exotic weeds, Habitat fragmentation, Changed hydrology
CAR2	Wooramel River	Degraded	Declining	Grazing pressure, Feral animals, Exotic weeds, Habitat fragmentation, Changed hydrology
GAS1	All fringing vegetation of riparian zones	Fair	Declining	Grazing pressure, Feral animals, Exotic weeds, Changed fire regimes
GAS2	Gascoyne Catchment Area	Fair	Declining to Static	Grazing pressure, Feral animals, Exotic weeds, Changed hydrology, Changed fire regimes
GAS3	Gascoyne Rivers	Degraded	Declining	Grazing pressure, Feral animals, Exotic weeds, Changed hydrology, Changed fire regimes
GAS3	Lyons Rivers	Degraded	Declining	Grazing pressure, Feral animals, Exotic weeds, Changed hydrology, Changed fire regimes
MUR1	All fringing vegetation of riparian zones	Fair	Declining to Static	Grazing pressure, Feral animals, Exotic weeds, Changed hydrology, Changed fire regimes
MUR2	Wooramel River	Degraded	Declining	Grazing pressure, Feral animals, Exotic weeds, Changed hydrology
MUR2	Murchison River	Degraded	Declining	Grazing pressure, Feral animals, Exotic weeds, Changed hydrology
YAL	Murchison River	Fair	Declining	Grazing pressure, Feral animals, Exotic weeds
YAL	Greenough River	Fair	Declining	Grazing pressure, Feral animals, Exotic weeds

Table 9.15. The Threatened Ecological Communities (from WATSCU) and other ecosystems at risk (from May and McKenzie, 2003) of the Gascoyne Murchison Region. Note: there are two endorsed TECs and both have Vulnerable status. The other communities may or may not be on the WATSCU priority community list and may or may not have a priority classification.

sub-IBRA	Community Description	Status
CAR1	Sea turtle nesting areas	other ecosystem at risk
CAR1	Marine environments generally (including Ningaloo reef, Exmouth Gulf, Shallow marine areas around Barrow Island and Montebellos)	other ecosystem at risk
CAR1	Stygofauna communities on North West Cape	other ecosystem at risk
CAR1	Ephemeral creekline drainage communities	other ecosystem at risk
CAR2	Hypersaline microbial community number 2 (Hamelin stromatolite)	other ecosystem at risk
CAR2	Mangrove communities dominated by Avicennia (Shark Bay) (B. Barton pers. comm.)	other ecosystem at risk
CAR2	Invertebrate assemblages of Callytharra Spring, Wooramel River (-255232S, 1153007E). Permanent Spring on the Wooramel river. High aquatic invertebrate diversity (W. Kay, M. Smith, M. Scanlon, S. Halse pers. comm.).	other ecosystem at risk
CAR2	Permanent water soaks and wetlands on western edge of the Kennedy Ranges (B. Barton pers. comm.). Not distinct floristically but are geologically, flora highly variable, classified same as Callytharra claypans (G. Keighery pers. comm.).	other ecosystem at risk
CAR2	Flora and fauna assemblages of the gorges of Wooramel River (B. Barton pers. comm., T. Brandis pers. comm.)	other ecosystem at risk
CAR2	Floodplains of the Carnarvon Basin, Wooramel and Gascoyne Rivers (Burbidge and McKenzie 1995; Wilcox and McKinnon 1992). Not in reserve system, is widespread but highly modified. Is a major break in floristics between tropics and south (G. Keighery pers. comm.).	other ecosystem at risk
CAR2	Plant assemblages dominated by Acacia sibilans (Myall) occurs. The number of trees is estimated to be very few, occurs on Yaringa Station and possibly Carbla and Woodleigh (J. Stretch pers. comm.).	other ecosystem at risk
CAR2	Acacia drephanophylla (Hamelin Wattle) on calcareous substrates. Regionally restricted. From Carnarvon Basin Land Systems >800km2.	other ecosystem at risk
CAR2	Assemblages of the Gascoyne Delta system (T. Brandis pers. comm.).	other ecosystem at risk
CAR2	Reptile assemblages of islands, gulfs and peninsulas, Shark Bay (Storr and Harold 1990)	other ecosystem at risk
CAR2	Plant assemblages (spinifex dominated) of sand dune mesa topping the Kennedy Range National Park (B. Barton pers. comm.)	other ecosystem at risk
CAR2	Invertebrate assemblages of Mooka Springs (-245253S, 1145827E). Spring in the Kennedy	other ecosystem at risk

sub-IBRA	Community Description	Status
	Range threatened by feral goats. Has rich representative invertebrate community (W. Kay, M. Smith, M. Scanlon, S. Halse pers. comm.).	
CAR2	Samphire communities of Lake MacLeod (Burbidge and McKenzie 1995)	other ecosystem at risk
CAR2	Inland Mangrove assemblage (Avicennia marina) of Lake MacLeod. Western shore, photograph in (Burbidge and McKenzie 1995).	other ecosystem at risk
CAR2	Fish assemblages of Blue Holes, Lake MacLeod. (Fish have been collected by Andrew Storey.)	other ecosystem at risk
CAR2	Lake MacLeod invertebrate assemblages. Saline aquatic community with strong marine affinities with particularly rich copepod element, is effectively a well developed, very rich birrida community with strong marine and terrestrial components with especially rich hypactacoid community (Halse et al. 2000). (A. Storey pers. comm.)	other ecosystem at risk
CAR2	Specific Seagrass Communities, Shark Bay and elsewhere. (Walker 1990, Walker 1989).	other ecosystem at risk
CAR2	River Land System vegetation on Gascoyne River in Carnarvon. (J. Stretch pers. comm.)	other ecosystem at risk
CAR2	Sponge community at Shark Bay. (R.I.T. Prince pers. comm.).	other ecosystem at risk
GAS1	Dwarf shrublands of the Ashburton catchment (Ashburton Downs – Kooline land system)	other ecosystem at risk
GAS1	Yadjiyugga Claypan	other ecosystem at risk
GAS1	Wetland systems of the Ashburton and Lyons drainage (including permanent and semi-perm pools, springs and	other ecosystem at risk
GAS1	Saltbush community, alluvial plains of Ashburton (type CHAT in Payne et al. 1988)	other ecosystem at risk
GAS1	Bluebush community, alluvial plains of Ashburton (type CHMA in Payne et al. 1988)	other ecosystem at risk
GAS1	Mulga creekline community, alluvial plains of Ashburton (type MUCR in Payne et al. 1988)	other ecosystem at risk
GAS2	Windich Springs	other ecosystem at risk
GAS2	Lake Carnegie	other ecosystem at risk
GAS2	Subterranean fauna of Calcrete aquifers	other ecosystem at risk
GAS3	Invertebrate assemblages of Mibbley pool (-245838, 1181343). Large relatively undisturbed freshwater pool on the upper Gascoyne River (therefore unusual). Until recently protected from stock by thick riparian vegetation. Shire has recently cleared a track to the pool which has allowed stock access (W.Kay, M.Smith, M.Scanlon, S.Halse pers. comm.).	other ecosystem at risk
GAS3	Invertebrate assemblages of Erong Springs (-252844, 1165236). High aquatic invertebrate diversity site in the Gascoyne area. (W.Kay, M.Smith, M.Scanlon, S.Halse pers. comm.).	other ecosystem at risk
GAS3	(-243627S, 1160303E). Permanent freshwater pool on the middle Gascoyne. (W.Kay, M.Smith, M.Scanlon, S.Halse pers. comm.).	other ecosystem at risk
GAS3	Invertebrate assemblages of Edithana Pool (-240725S, 1162932E) High quality river pool on the Lyons River. High invertebrate diversity. (W.Kay, M.Smith, M.Scanlon, S.Halse pers. comm.).	other ecosystem at risk

sub-IBRA	Community Description	Status
GAS3	Invertebrate assemblages of Cattle Pool (-241701S, 1164933E). High quality river pool on the Lyons River adjacent to Mt Augustus National Park. High invertebrate diversity. (W.Kay, M.Smith, M.Scanlon, S.Halse pers. comm.).	other ecosystem at risk
GAS3	Vegetation communities dominated by Eremophila species. Landor Station, North of racetrack. 26 Eremophila species in this area, one undescribed Eremophila occurs in a unique community (A.Brown pers. comm.).	other ecosystem at risk
GAS3	Chenopod community of Weelarana Station. Heavily grazed and trampled by cattle, camel, and rabbits. (Stephen van Leeuwen, pers comm.).	other ecosystem at risk
GAS3	Clay pan dominated by Nymphoides indica. One occurrence, located 70 km south of Newman. Others probably occur, and are also threatened by grazing.	other ecosystem at risk
GAS3	Eucalyptus ferriticola over trees on drainage lines in Gascoyne e.g. Doolgunna Station (K.Tinley pers. comm.)	other ecosystem at risk
GAS3	Critical Weight Range Mammals such as Macrotis lagotis, Dasycercus crassicaudata, Dasyurids.	other ecosystem at risk
GAS3	Stony short grass-forb association of the undulating terrain of the Gascoyne catchment (Wilcox and McKinnon 1992)	other ecosystem at risk
GAS3	Stony chenopod association of strew covered drainage plains of the Gascoyne catchment (Wilcox and McKinnon 1992)	other ecosystem at risk
GAS3	Jeeaila River Downs vegetation complexes. East of Mount Augustus (proposed Nature Reserve) (B.Barton pers. comm.).	other ecosystem at risk
GAS3	Plant assemblages of high diversity landscapes and unusual landforms being studied for the Ecological Management Unit, Gascoyne-Murchison Strategy e.g. Mt Arapiles (Milgun)	other ecosystem at risk
GAS3	Chenopod association of tributaries and major drainage lines of the Gascoyne catchment (Wilcox and McKinnon 1992)	other ecosystem at risk
GAS3	Mulga short grass-forb association of non-saline tributary drainage plains of the Gascoyne catchment (Wilcox and McKinnon 1992)	other ecosystem at risk
GAS3	Wanderrie association on sandy alluvial drainage plains of the Gascoyne catchment (Wilcox and McKinnon 1992)	other ecosystem at risk
GAS3	Stygofauna of the Carnegie Drainage system (Humphries)	other ecosystem at risk
GAS3	Plant assemblages of Robinson Range. Has populations of DRFs (Pityrodia augustensis) and several endemic Eremophila. Includes Mt Fraser and higher peaks. Is currently in very good condition but potentially subject to mining (A.Brown pers comm.).	other ecosystem at risk
GAS3	Invertebrate assemblages of Yinnietharra Cattle Pool. Permanent freshwater pool on the middle Gascoyne	other ecosystem at risk
GS1	Coastal heath communities at Steep Point (P. Brown pers. comm.)	other ecosystem at risk

sub-IBRA	Community Description	Status
GS1	Reptile assemblages of islands, gulfs and peninsulas, Shark Bay (Storr and Harold 1990)	other ecosystem at risk
MUR1	Depot Springs stygofauna community	VU
MUR1	Microbialite community of Harpers Lagoon. NNE of Kalgoorlie (R. Sarti pers. comm.)	other ecosystem at risk
MUR1	Mulga (Acacia aneura) shrublands with scattered chenopod low shrubs of the north-east Goldfields (Pringle et al. 1994 - site type 19)	other ecosystem at risk
MUR1	Silver saltbush (Atriplex bunburyana) low shrublands of the north-east Goldfields (Pringle et al. 1994 - site type 16)	other ecosystem at risk
MUR1	Mixed chenopod shrublands with mulga (Acacia aneura) overstorey of the north-east Goldfields (Pringle et al. 1994 - site type 18)	other ecosystem at risk
MUR1	Mulga (Acacia aneura) drainage line shrublands/woodlands with chenopod understoreys of the north-east Goldfields (Pringle et al. 1994 - site type 20)	other ecosystem at risk
MUR1	Upland small bluebush (Maireana spp.) species shrublands of the north-east Goldfields (Pringle et al. 1994 - site type 23)	other ecosystem at risk
MUR1	Stony ironstone mulga (Acacia aneura) shrublands of the north-east Goldfields Survey by Pringle et al. 1994 - site type 28)	other ecosystem at risk
MUR1	Stony bluebush (Maireana spp.) mixed shrublands of the north-east Goldfields (Pringle et al. 1994 - site type 22)	other ecosystem at risk
MUR1	Calcyphytic pearl bluebush (Maireana sedifolia) shrublands of the north-east Goldfields (Pringle et al. 1994 - site type 21)	other ecosystem at risk
MUR1	Calcrete platform woodlands/shrublands of the north-east Goldfields (Pringle et al. 1994 - site type 8)	other ecosystem at risk
MUR1	Plain mixed halophyte low shrublands of the north-east Goldfields (Pringle et al. 1994 - site type 9)	other ecosystem at risk
MUR1	Mount Linden Range banded ironstone ridge vegetation complex (G. Keighery and N. Gibson pers comm.)	other ecosystem at risk
MUR1	Mount Jumbo Range vegetation complex, Laverton area, northeast goldfields (G. Keighery and N. Gibson pers comm.; Hall, et al. 1994-not definitive; Beard 1974b-not definitive)	other ecosystem at risk
MUR1	Granite hill mixed shrublands of the north-east Goldfields Survey by Pringle et al. 1994 - site type 25 .	other ecosystem at risk
MUR1	Melaleuca sp. nov. Low Closed to Open Forest Strand Community Near Wiluna (Blackwell and Trudgen 1980)	other ecosystem at risk
MUR1	Calcyphytic casuarina acacia woodlands/shrublands of the north-east Goldfields (Pringle et al. 1994 - site type 7)	other ecosystem at risk
MUR1	Subterranean fauna of the Paroo Sub-Basin of the Lake Way Basin. Calcrete formations near	other ecosystem at risk

sub-IBRA	Community Description	Status
	Wiluna (B. Humphreys pers. comm.).	
MUR2	Assemblages of specific lake communities e.g. Lake Austin, Lake Annean (ANCA 1996 - Lake Annean) (R. Shepherd pers. comm.)	other ecosystem at risk
MUR2	Assemblages of the inland Granites (Murchison) (A. Brown, S. Hopper pers. comm.)	other ecosystem at risk
MUR2	Floodplains of the Carnarvon Basin, Wooramel and Gascoyne Rivers (Burbidge and McKenzie 1995; Wilcox and McKinnon 1992).	other ecosystem at risk
MUR2	Mixed halophytic shrublands MXHS; Murchison River catchment (Curry 1994) (R. Shepherd pers. comm.).	other ecosystem at risk
MUR2	Saltbush (Atriplex spp.) shrublands SALS; Murchison River catchment (Curry 1994) (R. Shepherd pers. comm.).	other ecosystem at risk
MUR2	Creekline grassy shrublands CRGS; Murchison River catchment (Curry 1994).	other ecosystem at risk
MUR2	Non-calcareous shrubby grasslands NCSG; Murchison River catchment (Curry 1994).	other ecosystem at risk
MUR2	Breakaway footslope chenopod low shrubland of the Sandstone-Yalgoo-Paynes Find area (Payne et al. 1998)	other ecosystem at risk
MUR2	Bluebush (Maireana spp.) shrublands BLUS; Murchison River catchment (Curry 1994).	other ecosystem at risk
MUR2	Stony snakewood (Acacia xiphophylla) shrublands SSWS; Murchison River catchment (Curry 1994).	other ecosystem at risk
MUR2	Alluvial plain snakewood chenopod shrubland (ASWS) of the Sandstone-Yalgoo-Paynes Find area (Payne et al. 1998)	other ecosystem at risk
MUR2	Hardpan mulga (Acacia aneura) shrublands HPMS; Murchison River catchment (Curry 1994)	other ecosystem at risk
MUR2	Stony mulga (Acacia aneura) mixed shrubland SMMS; Murchison River catchment (Curry 1994)	other ecosystem at risk
MUR2	Calcrete shrubby grasslands CSHG; Murchison River catchment (Curry 1994).	other ecosystem at risk
MUR2	Calcrete Eucalypt woodlands of Murchison River catchment (Curry 1994).	other ecosystem at risk
MUR2	Eucalyptus camaldulensis woodlands that are Major Mitchell nesting sites on Berringarrah and Milly Milly Stations along the Murchison River (N. McKenzie data) (P. Brown, R. Shepherd, B. Barton pers. comm.)	other ecosystem at risk
MUR2	Shrubland communities of lake frontages, Murchison area. Polelle Station good condition (A. Mitchell pers. comm.)	other ecosystem at risk
MUR2	Mount Narryer and Jack Hills vegetation complexes (R. Shepherd, B. Barton pers. comm.);	other ecosystem at risk
MUR2	Stony bluebush mixed shrubland (SBMS) of the Sandstone-Yalgoo-Paynes Find area (Payne et al. 1998)	other ecosystem at risk
MUR2	Hardpan plain mulga shrubland with scattered chenopods (HMCS) of the Sandstone-Yalgoo-Paynes Find area (Payne et al. 1998)	other ecosystem at risk

sub-IBRA	Community Description	Status
MUR2	Melaleuca wetlands and spinifex areas of the Lake System on Muggon Station (B. Barton, R. Shepherd pers. comm.)	other ecosystem at risk
MUR2	Marloo land system Mitchell Grass floodplain, top end type Mia Mia Station (K. Tinley pers. comm.)	other ecosystem at risk
MUR2	Merbla land system Unique treeless grassland (K. Tinley pers. comm.)	other ecosystem at risk
MUR2	Assemblages of the perched lake at Weld Range (K. Tinley Pers. comm.)	other ecosystem at risk
MUR2	CWR Mammals. Extant species include Dasycercus cristicauda, Species extinct in subregion include Macrotis lagotis, Pseudomys chapmanii.	other ecosystem at risk
MUR2	Aquatic fauna assemblages of Fish Holes on Doolgunna Station. Possibly have endemic fish and turtles (K. Tinley pers. comm.). Fish since collected and sent to Museum now awaiting ID.	other ecosystem at risk
MUR2	Subterranean fauna of the Murchison Basin. Calcrete formations north east of Cue (B. Humphreys pers. comm.).	other ecosystem at risk
YAL	Sago Bush on narrow drainage lines of Tindelarra Land System. Narrow bands of alluvial soils that are degraded (J. Stretch pers. comm.).	other ecosystem at risk
YAL	Plant assemblages dominated by Acacia grasbyi (miniritchie). Very widespread but only regenerates where no grazing (domestic or feral including rabbits) e.g. regeneration at Yuin mine reserve (J. Stretch pers. comm.).	other ecosystem at risk
YAL	Stony bluebush mixed shrubland (SBMS) of the Sandstone-Yalgoo-Paynes Find area (Payne et al. 1998)	other ecosystem at risk
YAL	Drainage tract acacia shrubland (DRAS) of the Sandstone-Yalgoo-Paynes Find area (Payne et al. 1998)	other ecosystem at risk
YAL	Alluvial plain snakewood chenopod shrubland (ASWS) of the Sandstone-Yalgoo-Paynes Find area (Payne et al. 1998)	other ecosystem at risk
YAL	Breakaway footslope chenopod low shrubland of the Sandstone-Yalgoo-Paynes Find area (Payne et al. 1998)	other ecosystem at risk
YAL	Lignum dominated plant assemblages of swamps of the Midwest e.g. at Thundelarra, Barnong Stations and Muggon (K. Tinley pers. comm.).	other ecosystem at risk
YAL	Plant assemblages of high diversity landscapes and unusual landforms of Lake Wooleen	other ecosystem at risk
YAL	Plant assemblages of high diversity landscapes and unusual landforms of silty sandy clay dunes on Muggon. Mt Gibson vegetation complex from NUR1 (p5).	other ecosystem at risk
YAL	Mt Gibson vegetation complex (G. Keighery and N. Gibson pers. comm.; Beard map).	other ecosystem at risk
YAL	Invertebrate assemblages of Granite pools	other ecosystem at risk
YAL	Critical weight range mammals (locally extinct species Dasycercus cristicauda, Dasyurus geoffroii,	other ecosystem at risk

sub-IBRA	Community Description	Status
	Isoodon auratus)	
YAL	Mt Singleton vegetation complex, Ninghan Station (A. Chant pers. comm.).	other ecosystem at risk
YAL	Tallering Peak vegetation complexes. Ironstone range. Threatened by mining (E.P. Branch).	other ecosystem at risk

Table 9.16. The Threatened and Priority bird fauna of the Gascoyne-Murchison region. This list excludes marine and island species. Summarised from May and McKenzie (2003), Johnstone *et* al. (2000) and records from the WA museum faunabase (see methods).

Family	Species	Common Name	Conservation Class
Psittacidae	*Pezoporus occidentalis*	Night Parrot	CR
Psittacidae	*Calyptorhynchus latirostris*	Short-billed Black-Cockatoo	E
Megapodiidae	*Leipoa ocellate*	Malleefowl	VU
Tytonidae	*Tyto novaehollandiae novaehollandiae*	Masked Owl (SW ssp)	P3
Maluridae	*Amytornis textiles*	Thick-billed Grasswren	P4
Burhinidae	*Burhinus grallarius*	Bush Stone-curlew	P4
Acanthizidae	*Calamanthus campestris*	Rufous Fieldwren	P4
Maluridae	*Amytornis striatus*	Striated Grasswren	P4
Otididae	*Ardeotis australis*	Australian Bustard	P4
Scolopacidae	*Numenius madagascariensis*	Eastern Curlew	P4
Falconidae	*Falco hypoleucos*	Grey Falcon	P4
Charadriidae	*Charadrius rubricollis*	Hooded Plover	P4
Psittacidae	*Polytelis alexandrae*	Princess Parrot	P4
Pomatostomidae	*Pomatostomus superciliosus*	White-browed Babbler	P4
Psittacidae	*Cacatua leadbeateri*	Major Mitchell's Cockatoo	Specially Protected
Falconidae	*Falco peregrinus*	Peregrine Falcon	Specially Protected

Table 9.17. The avifauna of the Gascoyne-Murchison region (see methods) showing the response groups of Johnstone et al (2000) and James *et al* (1999). Data has been sorted by conservation code and response groups. D decreasing, I increasing; [1] N not determined. [2] RE are species extinct in many regions, considered decreasers, V Variable response (increasers in some areas and decreasers in others).

Family	Species	Common Name	Conservation Class	Response in Johnstone *et al* (2000)[1]	Response in James *et al* (1999)[2]
Psittacidae	*Pezoporus occidentalis*	Night Parrot	CR		RE
Psittacidae	*Calyptorhynchus latirostris*	Short-billed Black-Cockatoo	E		
Tytonidae	*Tyto novaehollandiae novaehollandiae*	Masked Owl (SW ssp)	P3		D
Otididae	*Ardeotis australis*	Australian Bustard	P4	D	
Burhinidae	*Burhinus grallarius*	Bush Stone-curlew	P4	D	D
Maluridae	*Amytornis textiles*	Thick-billed Grasswren	P4	N	RE
Acanthizidae	*Calamanthus campestris*	Rufous Fieldwren	P4	N	D
Pomatostomidae	*Pomatostomus superciliosus*	White-browed Babbler	P4	N	
Maluridae	*Amytornis striatus*	Striated Grasswren	P4		D
Scolopacidae	*Numenius madagascariensis*	Eastern Curlew	P4		
Falconidae	*Falco hypoleucos*	Grey Falcon	P4		
Charadriidae	*Charadrius rubricollis*	Hooded Plover	P4		
Psittacidae	*Polytelis alexandrae*	Princess Parrot	P4		
Psittacidae	*Cacatua leadbeateri*	Major Mitchell's Cockatoo	S		D
Falconidae	*Falco peregrinus*	Peregrine Falcon	S		D
Megapodiidae	*Leipoa ocellate*	Malleefowl	VU	D	RE
Laridae	*Sterna nilotica*	Gull-billed Tern		N	
Laridae	*Sterna albifrons*	Little Tern		N	
Meliphagidae	*Lichmera indistincta*	Brown Honeyeater		D	I
Sylviidae	*Cincloramphus mathewsi*	Rufous Songlark		D	I
Hirundinidae	*Cheramoeca leucosternus*	White-backed swallow		D	I
Pelecanidae	*Pelecanus conspicillatus*	Australian Pelican		D	
Halcyonidae	*Dacelo leachii*	Blue-winged Kookaburra		D	
Acanthizidae	*Acanthiza apicalis*	Broad-tailed Thornbill		D	

Family	Species	Common Name	Conservation Class	Response in Johnstone *et al* (2000)[1]	Response in James *et al* (1999)[2]
Accipitridae	*Accipiter cirrocephalus*	Collared Sparrowhawk		D	
Laridae	*Sterna bergii*	Crested Tern		D	
Laridae	*Sterna nereis*	Fairy Tern		D	
Petroicidae	*Petroica cucullata*	Hooded Robin		D	
Phalacrocoracidae	*Phalacrocorax sulcirostris*	Little Black Cormorant		D	
Artamidae	*Artamus minor*	Little Woodswallow		D	
Accipitridae	*Pandion haliaetus*	Osprey		D	
Laridae	*Larus pacificus*	Pacific Gull		D	
Cuculidae	*Cuculus pallidus*	Pallid Cuckoo		D	
Phalacrocoracidae	*Phalacrocorax varius*	Pied Cormorant		D	
Haematopodidae	*Haematopus longirostris*	Pied Oystercatcher		D	
Maluridae	*Stipiturus malachurus*	Southern Emu-wren		D	
Accipitridae	*Circus assimilis*	Spotted Harrier		D	
Maluridae	*Malurus lamberti*	Variegated Fairy-wren		D	
Accipitridae	*Haliaeetus leucogaster*	White-bellied Sea-Eagle		D	
Casuariidae	*Dromaius novaehollandiae*	Emu		I	V
Falconidae	*Falco cenchroides*	Australian Kestrel		I	I
Charadriidae	*Vanellus tricolor*	Banded Lapwing		I	I
Artamidae	*Artamus cinereus*	Black-faced Woodswallow		I	I
Columbidae	*Ocyphaps lophotes*	Crested Pigeon		I	I
Psittacidae	*Cacatua roseicapilla*	Galah		I	I
Columbidae	*Geopelia striata*	Peaceful Dove		I	I
Motacillidae	*Anthus australis*	Richard's Pipit		I	I
Hirundinidae	*Hirundo neoxena*	Welcome Swallow		I	I
Charadriidae	*Charadrius melanops*	Black-fronted Dotterel		I	
Accipitridae	*Himantopus himantopus*	Black-winged Stilt		I	
Psittacidae	*Melopsittacus undulatus*	Budgerigar		I	

Family	Species	Common Name	Conservation Class	Response in Johnstone *et al* (2000)[1]	Response in James *et al* (1999)[2]
Acanthizidae	*Acanthiza uropygialis*	Chestnut-rumped Thornbill		I	
Laridae	*Sterna bengalensis*	Lesser Crested Tern		I	
Dicruridae	*Rhipidura phasiana*	Mangrove Grey Fantail		I	
Artamidae	*Artamus personatus*	Masked Woodswallow		I	
Laridae	*Sterna dougallii*	Roseate Tern		I	
Pachycephalidae	*Pachycephala rufiventris*	Rufous Whistler		I	
Laridae	*Sterna hybrida*	Whiskered Tern		I	
Zosteropidae	*Zosterops luteus*	Yellow White-eye		I	
Columbidae	*Streptopelia senegalensis*	Laughing Turtle-Dove		I	
Charadriidae	*Peltohyas australis*	Inland Dotterel		I	I
Psittacidae	*Calyptorhynchus banksii*	Red-tailed Black-Cockatoo		N	V
Columbidae	*Geophaps plumifera*	Spinifex Pigeon		N	V
Accipitridae	*Aquila audax*	Wedge-tailed Eagle		N	V
Cracticidae	*Cracticus tibicen*	Australian Magpie		N	I
Glareolidae	*Stiltia isabella*	Australian Pratincole		N	I
Corvidae	*Corvus coronoides*	Australian Raven		N	I
Psittacidae	*Barnardius zonarius*	Australian Ringneck		N	I
Acanthizidae	*Aphelocephala nigricincta*	Banded Whiteface		N	I
Accipitridae	*Elanus axillaris*	Black-shouldered Kite		N	I
Psittacidae	*Neophema bourkii*	Bourke's Parrot		N	I
Sylviidae	*Cincloramphus cruralis*	Brown Songlark		N	I
Columbidae	*Phaps chalcoptera*	Common Bronzewing		N	I
Hirundinidae	*Hirundo ariel*	Fairy Martin		N	I
Cracticidae	*Cracticus torquatus*	Grey Butcherbird		N	I
Pomatostomidae	*Pomatostomus temporalis*	Grey-crowned Babbler		N	I
Psittacidae	*Cacatua sanguinea*	Little Corella		N	I
Corvidae	*Corvus bennetti*	Little Crow		N	I

Family	Species	Common Name	Conservation Class	Response in Johnstone *et al* (2000)[1]	Response in James *et al* (1999)[2]
Dicruridae	*Grallina cyanoleuca*	Magpie-Lark		N	I
Cracticidae	*Cracticus nigrogularis*	Pied Butcherbird		N	I
Acanthizidae	*Aphelocephala leucopsis*	Southern Whiteface		N	I
Meliphagidae	*Acanthagenys rufogularis*	Spiny-cheeked Honeyeater		N	I
Pardalotidae	*Pardalotus striatus*	Striated Pardalote		N	I
Corvidae	*Corvus orru*	Torresian Crow		N	I
Ptilonorhynchidae	*Ptilonorhynchus maculatus*	Western Bowerbird		N	I
Meliphagidae	*Lichenostomus penicillatus*	White-plumed Honeyeater		N	I
Dicruridae	*Rhipidura leucophrys*	Willie Wagtail		N	I
Acanthizidae	*Acanthiza chrysorrhoa*	Yellow-rumped Thornbill		N	I
Meliphagidae	*Manorina flavigula*	Yellow-throated Miner		N	I
Passeridae	*Taeniopygia guttata*	Zebra Finch		N	I
Cinclosomatidae	*Cinclosoma castanotus*	Chestnut Quail-thrush		N	D
Cinclosomatidae	*Cinclosoma castaneothorax*	Chestnut-breasted Quail-thrush		N	D
Cinclosomatidae	*Psophodes occidentalis*	Chiming Wedgebill		N	D
Cracticidae	*Strepera versicolor*	Grey Currawong		N	D
Turnicidae	*Turnix velox*	Little Button-quail		N	D
Meliphagidae	*Certhionyx variegatus*	Pied Honeyeater		N	D
Pardalotidae	*Pardalotus rubricatus*	Red-browed Pardalote		N	D
Acanthizidae	*Pyrrholaemus brunneus*	Redthroat		N	D
Meliphagidae	*Phylidonyris melanops*	Tawny-crowned Honeyeater		N	D
Meliphagidae	*Epthianura albifrons*	White-fronted Chat		N	D
Maluridae	*Malurus leucopterus*	White-winged Fairy-wren		N	D
Aegothelidae	*Aegotheles cristatus*	Australian Owlet-nightjar		N	
Meliphagidae	*Certhionyx niger*	Black Honeyeater		N	
Anatidae	*Cygnus atratus*	Black Swan		N	

Family	Species	Common Name	Conservation Class	Response in Johnstone *et al* (2000)[1]	Response in James *et al* (1999)[2]
Cuculidae	*Chrysococcyx osculans*	Black-eared Cuckoo		N	
Campephagidae	*Coracina novaehollandiae*	Black-faced Cuckoo-Shrike		N	
Rallidae	*Gallinula ventralis*	Black-tailed Native-hen		N	
Climacteridae	*Climacteris melanura*	Black-tailed Treecreeper		N	
Maluridae	*Malurus pulcherrimus*	Blue-breasted Fairy-wren		N	
Accipitridae	*Haliastur indus*	Brahminy Kite		N	
Laridae	*Sterna anaethetus*	Bridled Tern		N	
Falconidae	*Falco berigora*	Brown Falcon		N	
Accipitridae	*Accipiter fasciatus*	Brown Goshawk		N	
Meliphagidae	*Melithreptus brevirostris*	Brown-headed Honeyeater		N	
Laridae	*Sterna caspia*	Caspian Tern		N	
Psittacidae	*Nymphicus hollandicus*	Cockatiel		N	
Pachycephalidae	*Oreoica gutturalis*	Crested Bellbird		N	
Meliphagidae	*Epthianura tricolor*	Crimson Chat		N	
Anhingidae	*Anhinga melanogaster*	Darter		N	
Columbidae	*Geopelia cuneata*	Diamond Dove		N	
Acanthizidae	*Gerygone tenebrosa*	Dusky Gerygone		N	
Ardeidae	*Ardea sacra*	Eastern Reef Egret		N	
Rallidae	*Fulica atra*	Eurasian Coot		N	
Pachycephalidae	*Pachycephala pectoralis*	Golden Whistler		N	
Phalacrocoracidae	*Phalacrocorax carbo*	Great Cormorant		N	
Dicruridae	*Rhipidura fuliginosa*	Grey Fantail		N	
Pachycephalidae	*Colluricincla harmonica*	Grey Shrike-thrush		N	
Anatidae	*Anas gracilis*	Grey Teal		N	
Meliphagidae	*Lichenostomus plumulus*	Grey-fronted Honeyeater		N	

Family	Species	Common Name	Conservation Class	Response in Johnstone *et al* (2000)[1]	Response in James *et al* (1999)[2]
Campephagidae	*Coracina maxima*	Ground Cuckoo-Shrike		N	
Podicipedidae	*Poliocephalus poliocephalus*	Hoary-headed Grebe		N	
Cuculidae	*Chrysococcyx basalis*	Horsfield's Bronze-Cuckoo		N	
Accipitridae	*Aquila morphnoides*	Little Eagle		N	
Phalacrocoracidae	*Phalacrocorax melanoleucos*	Little Pied Cormorant		N	
Dicaeidae	*Dicaeum hirundinaceum*	Mistletoebird		N	
Psittacidae	*Platycercus varius*	Mulga Parrot		N	
Meliphagidae	*Epthianura aurifrons*	Orange Chat		N	
Anatidae	*Anas superciliosa*	Pacific Black Duck		N	
Passeridae	*Emblema pictum*	Painted Finch		N	
Meropidae	*Merops ornatus*	Rainbow Bee-eater		N	
Meliphagidae	*Anthochaera carunculata*	Red Wattlebird		N	
Halcyonidae	*Todiramphus pyrrhopygia*	Red-backed Kingfisher		N	
Charadriidae	*Charadrius ruficapillus*	Red-capped Plover		N	
Petroicidae	*Petroica goodenovii*	Red-capped Robin		N	
Charadriidae	*Erythrogonys cinctus*	Red-kneed Dotterel		N	
Psittacidae	*Neophema petrophila*	Rock Parrot		N	
Maluridae	*Stipiturus ruficeps*	Rufous-crowned Emu-wren		N	
Laridae	*Larus novaehollandiae*	Silver Gull		N	
Zosteropidae	*Zosterops lateralis*	Silvereye		N	
Alaudidae	*Mirafra javanica*	Singing Bushlark		N	
Meliphagidae	*Lichenostomus virescens*	Singing Honeyeater		N	
Acanthizidae	*Acanthiza robustirostris*	Slaty-backed Thornbill		N	
Acanthizidae	*Acanthiza iredalei*	Slender-billed Thornbill		N	
Petroicidae	*Drymodes brunneopygia*	Southern Scrub-robin		N	
Maluridae	*Malurus splendens*	Splendid Fairy-wren		N	
Caprimulgidae	*Eurostopodus argus*	Spotted Nightjar		N	

Family	Species	Common Name	Conservation Class	Response in Johnstone *et al* (2000)[1]	Response in James *et al* (1999)[2]
Ardeidae	*Butorides striatus*	Striated Heron		N	
Phasianidae	*Coturnix pectoralis*	Stubble Quail		N	
Podargidae	*Podargus strigoides*	Tawny Frogmouth		N	
Hirundinidae	*Hirundo nigricans*	Tree Martin		N	
Neosittidae	*Daphoenositta chrysoptera*	Varied Sittella		N	
Procellariidae	*Puffinus pacificus*	Wedge-tailed Shearwater		N	
Acanthizidae	*Smicrornis brevirostris*	Weebill		N	
Petroicidae	*Eopsaltria australis*	WesternYellow Robin		N	
Accipitridae	*Haliastur sphenurus*	Whistling Kite		N	
Pachycephalidae	*Pachycephala lanioides*	White-breasted Whistler		N	
Acanthizidae	*Sericornis frontalis*	White-browed Scrubwren		N	
Climacteridae	*Climacteris affinis*	White-browed Treecreeper		N	
Ardeidae	*Ardea novaehollandiae*	White-faced Heron		N	
Meliphagidae	*Phylidonyris albifrons*	White-fronted Honeyeater		N	
Ardeidae	*Ardea pacifica*	White-necked Heron		N	
Campephagidae	*Lalage tricolor*	White-winged Triller		N	
Threskiornithidae	*Platalea flavipes*	Yellow-billed Spoonbill		N	
Accipitridae	*Hamirostra melanosternon*	Black-breasted Buzzard		N	D
Psittacidae	*Neophema splendida*	Scarlet-chested Parrot			RE
Ardeidae	*Ardea garzetta*	Little Egret			I
Artamidae	*Artamus leucorynchus*	White-breasted Woodswallow			I
Gruidae	*Grus rubicunda*	Brolga			D
Meliphagidae	*Lacustroica whitei*	Grey Honeyeater			D
Accipitridae	*Elanus caeruleus*	Letter-winged kite			D
Podicipedidae	*Tachybaptus novaehollandiae*	Australasian Grebe			
Falconidae	*Falco longipennis*	Australian Hobby			

Family	Species	Common Name	Conservation Class	Response in Johnstone *et al* (2000)[1]	Response in James *et al* (1999)[2]
Anatidae	*Tadorna tadornoides*	Australian Shelduck			
Rallidae	*Porzana fluminea*	Australian Spotted Crake			
Anatidae	*Chenonetta jubata*	Australian Wood Duck			
Rallidae	*Porzana pusilla*	Baillon's Crake			
Recurvirostridae	*Cladorhynchus leucocephalus*	Banded Stilt			
Tytonidae	*Tyto alba*	Barn Owl			
Scolopacidae	*Limosa lapponica*	Bar-tailed Godwit			
Anatidae	*Oxyura australis*	Blue-billed Duck			
Rallidae	*Gallirallus philippensis*	Buff-banded Rail			
Passeridae	*Lonchura castaneothorax*	Chestnut-breasted Mannikin			
Scolopacidae	*Tringa nebularia*	Common Greenshank			
Scolopacidae	*Tringa hypoleucos*	Common Sandpiper			
Scolopacidae	*Calidris ferruginea*	Curlew Sandpiper			
Rallidae	*Gallinula tenebrosa*	Dusky Moorhen			
Psittacidae	*Neophema elegans*	Elegant Parrot			
Apodidae	*Apus pacificus*	Fork-tailed Swift			
Pachycephalidae	*Pachycephala inornata*	Gilbert's Whistler			
Sylviidae	*Cisticola exilis*	Golden-headed Cisticola			
Charadriidae	*Charadrius leschenaultii*	Greater Sand Plover			
Scolopacidae	*Tringa brevipes*	Grey-tailed Tattler			
Petroicidae	*Microeca fascinans*	Jacky Winter			
Halcyonidae	*Dacelo novaeguineae*	Laughing Kookaburra			
Fregatidae	*Fregata ariel*	Lesser Frigatebird			
Sylviidae	*Megalurus gramineus*	Little Grassbird			
Accipitridae	*Circus aeruginosus*	Marsh Harrier			
Ardeidae	*Nycticorax caledonicus*	Nankeen Night Heron			
Rostratulidae	*Rostratula benghalensis*	Painted Snipe			

Family	Species	Common Name	Conservation Class	Response in Johnstone *et al* (2000)[1]	Response in James *et al* (1999)[2]
Anatidae	*Malacorhynchus membranaceus*	Pink-eared Duck			
Recurvirostridae	*Recurvirostra novaehollandiae*	Red-necked Avocet			
Scolopacidae	*Calidris ruficollis*	Red-necked Stint			
Psittacidae	*Polytelis anthopeplus*	Regent Parrot			
Scolopacidae	*Arenaria interpres*	Ruddy Turnstone			
Climacteridae	*Climacteris rufa*	Rufous Treecreeper			
Halcyonidae	*Todiramphus sanctus*	Sacred Kingfisher			
Scolopacidae	*Calidris acuminata*	Sharp-tailed Sandpiper			
Strigidae	*Ninox novaeseelandiae*	Southern Boobook			
Accipitridae	*Hamirostra isura*	Square-tailed Kite			
Threskiornithidae	*Threskiornis spinicollis*	Straw-necked Ibis			
Sylviidae	*Megalurus timoriensis*	Tawny Grassbird			
Acanthizidae	*Gerygone fusca*	Western Gerygone			
Artamidae	*Artamus superciliosus*	White-browed Woodswallow			
Dicruridae	*Rhipidura albicauda*	White-tailed Grey Fantail			
Scolopacidae	*Tringa glareola*	Wood Sandpiper			

Table 9.18. The Threatened and Priority vertebrate fauna of the Gascoyne-Murchison region. This list excludes marine and island species. From May and McKenzie (2003).

Group	Species	Status
Fish	*Milyeringa veritas*	V
Fish	*Ophisternon candidum*	V
Fish	*Leiopotherapon ahenius*	P4
Mammal	*Notoryctes typhlops*	E
Mammal	*Dasycercus cristicauda*	V
Mammal	*Macrotis lagotis*	V
Mammal	*Petrogale lateralis*	V
Mammal	*Rhinonicteris aurantius*	V
Mammal	*Macroderma gigas*	P4
Mammal	*Pseudomys chapmani*	P4
Mammal	*Sminthopsis longicaudata*	P4
Reptile	*Egernia stokesii badia*	E
Reptile	*Ctenophorus yinnietharra*	V
Reptile	*Ctenotus zastictus*	V
Reptile	*Egernia kintorei*	V
Reptile	*Diplodactylus kenneallyi*	P2

Table 9.19. The Threatened and Priority invertebrate fauna of the Gascoyne-Murchison region. From May and McKenzie (2003).

Group	Species	Status
Arachnid	*Bamazomus sp. Nov. (WAM #95/748)*	E
Arachnid	*Draculoides bramstokeri*	E
Arachnid	*Draculoides sp. Nov (WAM # 96/1 15 1)*	E
Arachnid	*Hyella sp. nov. (BES 1154.2525.2546.2554*	E
Crustacean	*Bogidoma australis*	E
Crustacean	*Lasionectes exleyi*	E
Crustacean	*Liagoceradocus branchialis*	E
Crustacean	*Liagoceradocus subthalassicus*	E
Crustacean	*Nedsia fragilis*	E
Crustacean	*Nedsia humphreysi*	E
Crustacean	*Nedsia hurlberti*	E
Crustacean	*Nedsia marosculptilis*	E
Crustacean	*Nedsia straskraba*	E
Crustacean	*Nedsia sulptilis*	E
Crustacean	*Nedsia urifimbriata*	E
Crustacean	*Stygiocaris lancifera*	E
Millipede	*Stygiochiropus peculiaris*	C
Millipede	*Speleostrophus nesiotes*	V
Millipede	*Stygiochiropus isolatus*	V
Millipede	*Stygiochiropus sympatricus*	V

Table 9.20. Conservation categories for TECs, Threatened flora and Threatened fauna used by CALM for the management of threatened taxa.

Conservation Category	Definition
Presumed Destroyed (PD) – Ecological Communities	No examples are left OR has been extensively modified that it is unlikely to recover in the foreseeable future
Extinct (Ex) – Flora or Fauna taxa	No known occurrences of flora or fauna taxa to be extant either in the wild or in captivity.
Critically Endangered (CR)	Subject to major contraction in area OR was already of limited distribution, and is in danger of severe modification or destruction in the immediate future
Endangered (E)	Subject to major contraction in area OR was already of limited distribution, and is in danger of significant modification or destruction in the near future
Vulnerable (VU)	Declining or declined in distribution and/or condition and whose ultimate security has not been secured OR still widespread but will become CR, EN or PD in the near future if threatening processes continue or begin to operate
Priority Ecological Communities (P1, P2, P3, P4, P5)	Possible threatened ecological communities, flora or fauna species that do not meet the stringent survey criteria are added to the Department's Priority Lists under Priorities 1, 2 and 3. Ecological Communities, flora or fauna species that are adequately known, are rare but not threatened, or meet criteria for Near Threatened, or that have been recently removed from the threatened list, are placed in Priority 4. These require regular monitoring. Conservation Dependent ecological communities, flora or fauna species are placed in Priority 5

Attachment 10 - Distance to water

Area of land types within various distances from water

Lease infrastructure maps are maintained by the Department of Agriculture. These maps contain all known permanent watering points, with the proviso that many of the maps may be ten or so years out of date and new or abandoned waters since that time will not be mapped. Nevertheless, they contain most of the permanent watering points known to exist in the pilot project region.

These watering points were overlain with land resource maps aggregated into one of 44 land types found in the pastoral areas of the state. The percent of each and type within various distances from water was then calculated (Table 10.1). Only pastoral leasehold land and land categorised as ‘Other Reserve’ was included in the analysis. Most of the parcels of ‘Other Reserve’ are unfenced areas within pastoral leasehold land and can therefore be considered to be subject to the same grazing pressures as leasehold land.

There is only one land type (#30) in which more than 50 per cent of the area is beyond six km from permanent water (Table 10.1). Twenty-five percent of this land type is beyond 15 km from permanent water. For all other land types, 10 per cent or less is beyond 15 km. Seven land types have no areas beyond 15 km. These seven land types make up about 14 per cent of the pastoral land in the region and include some of the major alluvial systems. Six land types have at least 50 per cent of their area within three km of water.

A separate analysis was not done for Department of Conservation and Land Management (CALM) held land because much of this land in the pilot project region has only recently been acquired from the pastoral estate and therefore still contains, or recently contained, artificial watering points (see Attachment 7). However, where CALM held land and Unallocated Crown Land represent at least 10 per cent of the total area of that land type, it might be expected that eventually much of that land would become remote from water. In Table 10.1 those land types are marked with an asterisk.

Table 10.1. The percentage of each land type (aggregated land systems) on pastoral leasehold land, at various distances from permanent water. Where CALM held land and Unallocated Crown Land total at least 10% of the total area of each land type under pastoral tenure, the land type is marked with an asterik (*).

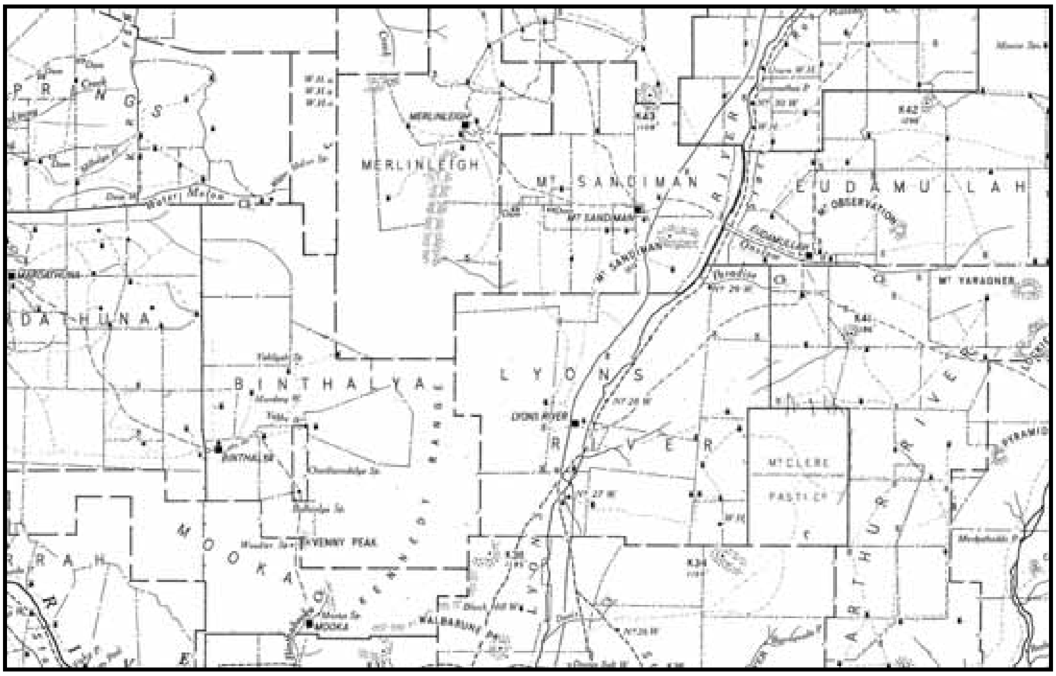
Land type	Area (ha)	Less than 3km (%)	3 – 6 km (%)	6 - 9 km (%)	9 – 12 km (%)	12 – 15 km (%)	Greater than 15km (%)	Greater than 6km (%)
1. Hills & ranges with Acacia shrublands (*)	4,609,370	26	46	16	7	3	2	27
2. Hills & ranges with spinifex grasslands (*)	305,146	20	41	18	9	6	7	39
5. Mesas, breakaways & stony plains with Acacia or Eucalypt woodlands & halophytic shrublands	3,087,444	34	48	10	4	2	2	18
6. Mesas, breakaways & stony plains with spinifex grasslands (*)	716	60	33	7			0	7
9. Low hills with Eucalypt or Acacia woodlands with halophytic undershrubs	590,599	33	37	9	7	4	10	30
10. Low hills & stony plains with Acacia shrublands	2,315,078	33	50	12	4	1	1	17
15. Gritty-surfaced plains & granite tors & domes with Acacia shrublands	1,026,950	45	50	3	1	1	1	5
16. Stony plains with Acacia shrublands	1,568,248	36	49	9	3	1	3	15
17. Stony plains with Acacia shrublands & halophytic shrublands	3,846,090	41	46	7	2	1	3	13
18. Stony plains with spinifex grasslands (*)	239,252	18	43	23	9	5	2	39
25. Sandplains & occasional dunes with grassy Acacia shrublands	2,963,915	39	51	8	1	0	0	10
26. Sandplains with Acacia, mallees & heath (*)	1,489,321	34	41	13	5	3	4	25
27. Sandplains & drainage floors with Acacia & halophytic shrublands	223,713	43	46	11	0	0	0	11
28. Sandplains & occasional dunes with spinifex grasslands (*)	5,140,924	24	43	15	7	4	6	33
29. Sandy plains with Acacia shrublands & wanderrie grasses (*)	1,863,504	37	42	11	4	2	3	20

Land type	Area (ha)	Less than 3km (%)	3 – 6 km (%)	6 - 9 km (%)	9 – 12 km (%)	12 – 15 km (%)	Greater than 15km (%)	Greater than 6km (%)
30. Plains with Eucalypt woodlands with non-halophytic undershrubs (*)	298,442	21	28	12	8	6	25	51
31. Wash plains on hardpan with mulga shrublands	4,660,419	50	38	6	3	1	1	11
32. Wash plains and sandy banks on hardpan, with mulga shrublands & wanderrie grasses or spinifex	4,436,031	52	40	4	2	1	1	8
34. Alluvial plains with Acacia shrublands	443,544	36	47	11	5	0	0	16
35. Alluvial plains with eucalypt woodlands and halophytic undershrubs (*)	263,583	17	36	22	14	6	5	47
36. Alluvial plains with halophytic shrublands	2,133,803	49	39	9	2	1	0	12
37. Alluvial plains with currant bush shrublands	1,482,300	28	44	14	4	3	8	29
38. Alluvial & sandy plains with soft spinifex grasslands	305,130	32	34	14	9	6	5	34
39. Alluvial plains with tussock grasslands	154,635	50	47	3	0	0	0	3
40. Calcrete plains with Acacia grasslands	823,104	52	41	6	1	0	1	8
41. Calcrete plains with spinifex	37,509	26	45	22	1	1	4	29
42. River plains with grassy woodlands and tussock grasslands	536,207	51	42	6	1	0	0	8
43. Salt lakes and fringing alluvial plains with halophytic shrublands (*)	1,424,766	23	45	16	7	4	5	32
44. Coastal plains, cliffs, dunes, mudflats & beaches; various vegetation (*)	318,904	38	31	14	9	5	3	32

Changes in distance to water since World War II

During the Second World War the Department of Lands and Surveys collated information on pastoral leasehold infrastructure. Maps showing this infrastructure were then released through the 1950s at a scale of 1 inch to 10 mile, i.e. 1:633,600 (Figure 10.1). These maps provide an opportunity to compare watering point distribution from around 1950 with current watering point distribution.

Figure 10.1. Sample of the 1:10 mile infrastructure map produced by the Department of Lands and Surveys following World War II. Carnarvon map sheet, released in 1951.



Watering points were digitised from an arbitrary sample of the Carnarvon map sheet (a different area to that shown in Figure 10.1). The sample area was then compared with the contemporary watering point distribution.

Much of the land was already well developed by the 1950s (Figure 10.2). However by the 1990s there was a large increase in the number of waters, particularly along river systems where permanent and semi-permanent river pools had previously been the only watering points available (Figure 10.3). By about 1950, 66 per cent of the land was within six km from water. By the 1990s, this had increased to 90 per cent.

Figure 10.2. Distance from permanent water circa 1950 for a sample of the pilot region

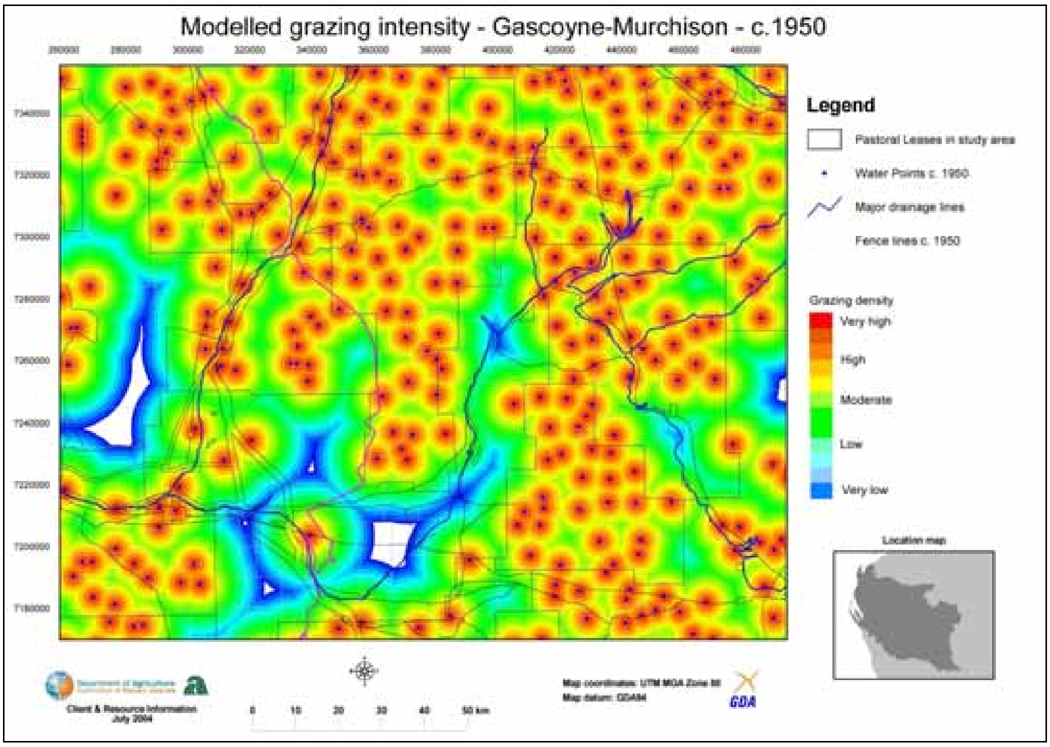
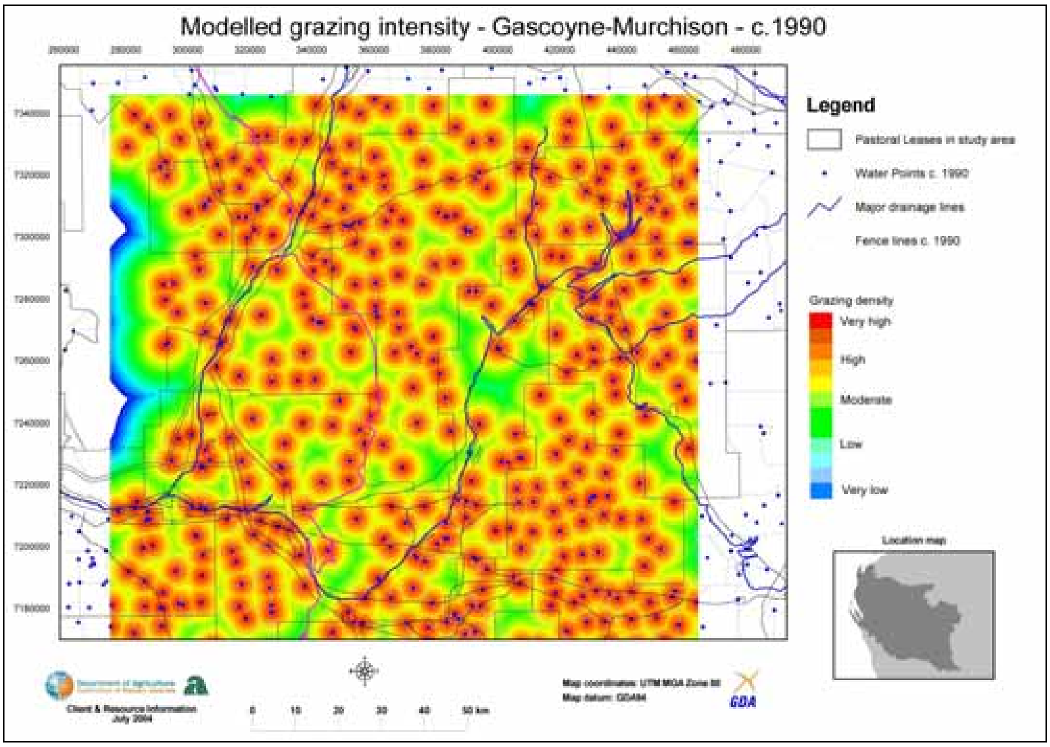
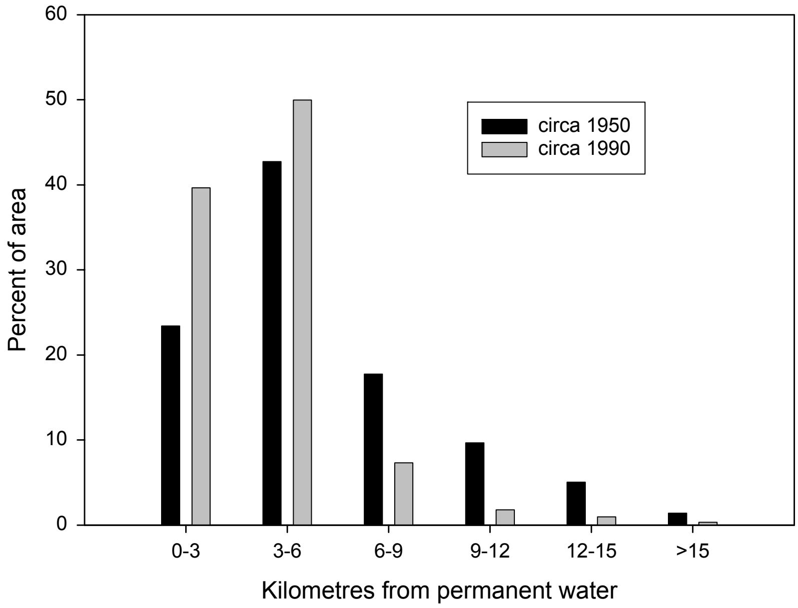


Figure 10.3. Distance from permanent water circa 1990 for a sample of the pilot region



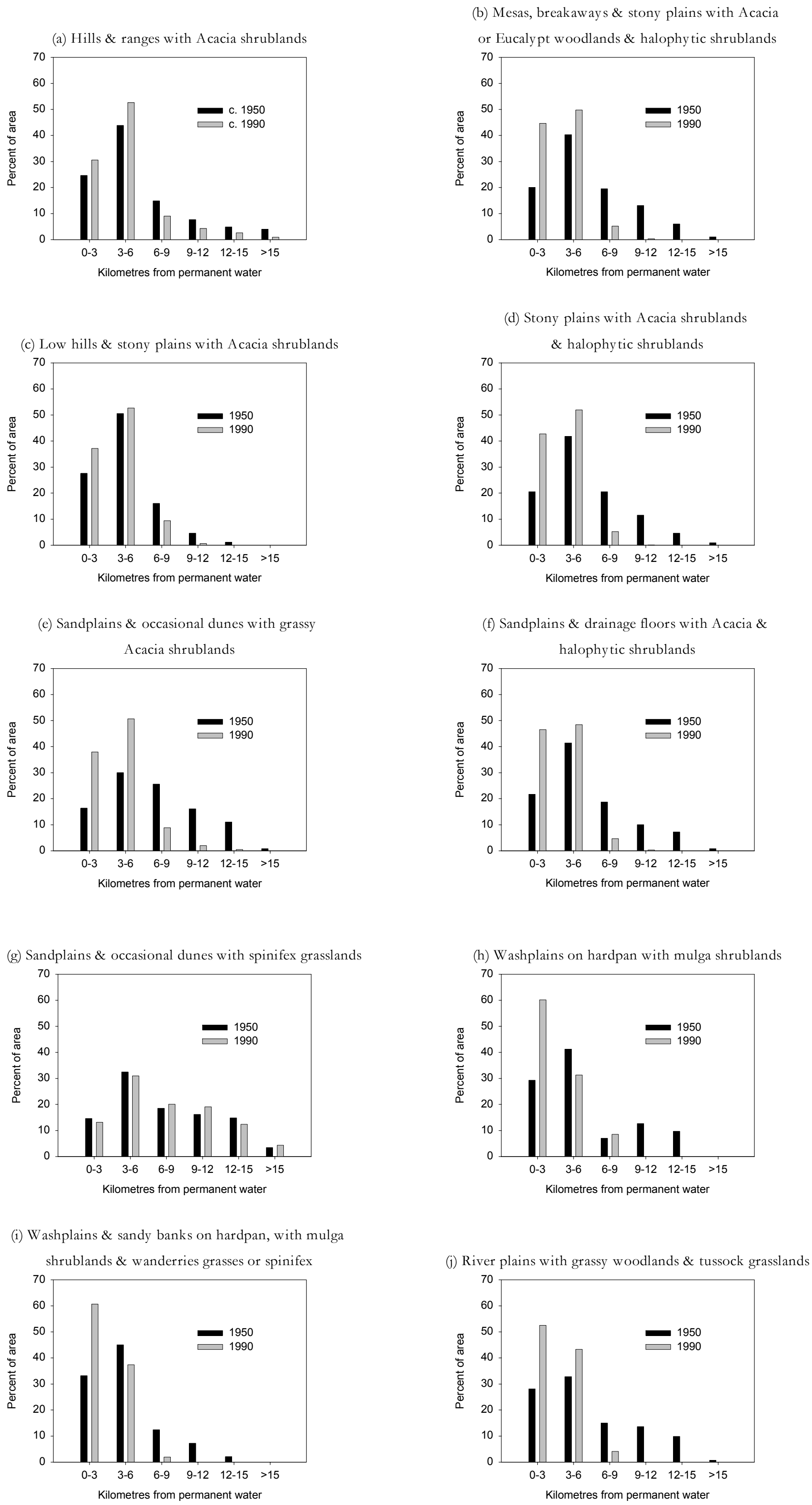
In the 1990s, there was less land at greater distances from water and more land close to water compared to the 1950s, in the sample area (Figure 10.4).

Figure 10.4. Frequency histogram of distance from water for a sample of the pilot project region circa 1950 and circa 1990.



This pattern was found across all land types (Figure 10.5) although the change was most pronounced in highly productive and fragile systems such as ‘River plains with grassy woodlands & tussock grasslands’ (Figure 10.5j) and ‘Sandplains & drainage floors with Acacia & halophytic shrublands’ (Figure 10.5f). On only one land type, the resilient and low productivity ‘Sandplains & occasional dunes with spinifex grasslands’ (Figure 10.5g) was the watering point distribution largely unchanged since the 1950s.

Figure 10.5. Distance from water (c. 1950 & c. 1990) for all land types in the sample area.



Attachment 11 - References

Bureau of Meteorology (1998). *Gascoyne-Murchison Western Australia - climatic survey.*, Commonwealth of Australia, Canberra.

Department of Western Australia (2001) (unpublished). *Draft 'Managing the rangelands of Western Australia. A framework for the future.*' http://www.gms.wa.gov.au/documents/mtr.pdf

Department of Agriculture Western Australia (2004). *Gascoyne Murchison Strategy Annual Report 2003-2004 and Final Report.* http://www.gms.wa.gov.au/documents/Gascoyne%20Murchison%20Strategy%2004.pdf

Department of the Environment and Heritage (2005). A natural meeting place. *Natural Heritage. The Journal of the Natural Heritage Trust,* **24**, winter 2005, p 10, Australian Government, Canberra.

Australian Bureau of Statistics (2004). *Social and economic profiles for selected regions within Australia's rangelands 2004.* National Land and Water Resources Audit, Canberra.

Bartle, R. (2004). *Report on the outcomes and highlights of the Gascoyne Murchison Strategy benchmarking, financial advice and business review project conducted by Resource Consulting Services 1999–2000, 2000–2001 and 2001–2002.* Resource Consulting Services.

Bastin, G. and members of the ACRIS Management Committee (2005). *Australian Collaborative Rangeland Information System: reporting change in the rangelands.* National synthesis of reports from pilot regions. http://www.deh.gov.au/land/management/rangelands/acris/index.html

Beard, J.S. (1990). *Plant life of Western Australia*. Kangaroo Press. Kenthurst NSW.

Braddick, L. (2005). *Evaluation of the Ecosystem Management Understanding (EMU) project: A survey of participants.* Miscellaneous report of the Centre for the Management of Arid Environments, Curtin University of Technology.

Brandis, A. (2004). *Report to REMP Committee – CAR reserve System establishment in the GMS.* Unpublished report. http://www.gms.wa.gov.au/documents/concludingreportforgmsrempmtg23aug04.pdf

Burnside, D., Holm, A., Payne, A. and Wilson, G. (1995). *Reading the rangeland: a guide to the arid shrublands of Western Australia.* Department of Agriculture, Perth Western Australia.

Cowan, M. (2003) Gascoyne 2. In: May, J. and McKenzie, N. (eds.) *A Biodiversity Audit of Western Australia's 53 Biogeographic Subregions in 2002.* Dept. CALM: Perth, 233–239.

Dames and Moore NRM (1999). *Baseline evaluation of values, attitudes and behaviour in the Gascoyne-Murchison. Final Report*. Unpublished report prepared for the

Gascoyne-Murchison Strategy Management Team and Agriculture Western Australia.

Eldridge, D.J., Westoby, M. & Stanley, R.J. (1990) Population dynamics of the perennial rangeland shrubs *Atriplex vesicaria, Maireana astrotricha* and *M. pyramidata* under grazing. *Journal of Applied Ecology,* **27,** 502–512.

Gascoyne – Murchison Rangeland Strategy Steering Group (1997). *Gascoyne – Murchison Rangeland Strategy, report to Cabinet Sub Committee*. Unpublished report, Agriculture Western Australia.

Hacker, R.B. (1984). Vegetation dynamics in a grazed mulga shrubland community. I the mid-storey shrubs. *Australian Journal of Botany*, **32**, 239–249.

Hacker, R.B. (1986). *Analysis of WARMS data - some alternatives*. Unpublished paper presented to the Rangeland Management Branch Conference, Department of Agriculture Western Australia, January 1986.

Hacker, R.B., Wang, K., Richmond, G.S. & Lindner, R.K. (1991). IMAGES: An integrated model of an arid grazing ecological system. *Agricultural Systems,* **37,** 119–163.

Halse, S., Scanlon, M.D. and Cocking, J.S. (2001). *First National Assessment of River Health: Western Australia Program.* Department of Conservation and Land Management, Wanneroo.

Holm, A.McR., Burnside, D.G. & Mitchell, A.A. (1987). The development of a system for monitoring trend in range condition in the arid shrublands of Western Australia. *The Australian Rangeland Journal,* **9,** 14–20.

Holm, A. McR. (2001). *Development of information products for rangeland managers. A contract with Agriculture Western Australia to develop and recommend methods for the summary and presentation of Landscape Function Analysis (LFA) data for the Western Australian Rangeland Monitoring System (WARMS).* Unpublished consultant's report.

Holm, A. McR., Watson, I.W., Loneragan, W.A. and Adams, M.A. (2003). Loss of patch scale heterogeneity on primary productivity and rainfall-use efficiency. *Basic and Applied Ecology.* **4,** 569–578.

Johnstone, R.E., Burbidge, A.H. and Stone, P. (2000). Birds of the Southern Carnarvon Basin, Western Australia: contemporary patterns of occurrence. In: *Biodiversity of the southern Carnarvon Basin* (Burbidge, A.H., Harvey, M.S. and McKenzie, N.L.). Western Australian Museum, Perth, 371–448

James, C.D., Landsberg, J. and Morton, S.R. (1999) Provision of watering points in the Australian arid zone: a review of effects on biota. *Journal of Arid Environments,* **41**, 87–121.

James, C.D., Landsberg, J. and Morton, S. (1999). Provision of watering points in Australia Rangelands: a literature review of effects on biota. In: *The effects of artificial sources of water on rangeland biodiversity.* (Landsberg, J., James, C.D., Morton, S.R., Hobbs, T.J., Stol, J., Drew, A. and Tongway, H). Commonwealth Department of Environment and Heritage, Canberra, 107–129.

Keighery, G. and Longman, V. (2004) The naturalised vascular plants of Western Australia 1: Checklist, environmental weeds and distribution in IBRA regions. *Plant Protection Quarterly,* **19**, 12–33.

Longley, P. (2000). *Gascoyne Murchison Strategy - access to commercial finance project. Economic overview of pastoral businesses.* Unpublished report of the Gascoyne-Murchison Strategy. http://www.gms.wa.gov.au/documents/access%20to%20finance%20plongley.pdf

Ludwig, J., Tongway, D., Freudenberger, D., Noble, J. and Hodgkinson, K. (1997) *Landscape ecology, function and management: principles from Australia's rangelands.* CSIRO Publishing, Melbourne, Victoria.

May, J. and McKenzie, N. (eds.) (2003) *A Biodiversity Audit of Western Australia's 53 Biogeographic Subregions in 2002.* Department of Conservation and Land Management, Perth.

McKeon, G.M., Cunningham, G.M., Hall, W.B., Henry, B.K., Owens, J.S., Stone, G.S. and Wilcox, D.G. (2004). Degradation and recovery episodes in Australia's rangelands: An anthology. In:. *Pasture degradation and recovery in Australia's rangelands. Learning from history.* (eds: McKeon, G.M., Hall, W. Henry, B.H., Stone, G. and Watson, I.W.). Queensland Department of Natural Resources, Mines and Energy, Brisbane, Australia, 256 pp.

Morton, S.R., Short, J and Barker, R.D. (1995). *Refugia for Biological Diversity in Arid and Semi-arid Australia.* Department of Environment, Sport and Territories, Canberra.

Rangelands NRM Co-ordinating Group (2005). *A strategy for managing the natural resources of Western Australia's rangelands. A draft for public comment and review.* Rangelands NRM Co-ordinating Group. http://strategy.rangelandswa.info/

Payne A.L. Curry, P.J. and Spencer, G.F. (1987). *An inventory and condition survey of the Carnarvon Basin, Western Australia*. Western Australian Department of Agriculture, Technical Bulletin No. 73.

Payne, A.L., Van Vreeswyk, A.M.E., Pringle, H.J.R., Leighton, K.A. and Hennig, P. (1998). *An inventory and condition survey of the Sandstone-Yalgoo-Paynes Find area, Western Australia.* Agriculture Western Australia Technical Bulletin No. 90.

Pringle, H.J.R. (2002). The Regional Environmental Management Program of the Gascoyne-Murchison Strategy. In: *Shifting Camp, Conference Proceedings of the 12th Biennial Conference of the Australian Rangeland Society* (eds. Nicolson, S. and Wilcox, D.), Kalgoorlie Western Australia, September 2002, 338–339.

Pringle, H. and Payne, A. (1997). Rangeland Survey in Western Australia: an evolving process. *Rangelands,* **19,** 18–21.

Pringle, H. and Tinley, K. (2003). Are we overlooking critical geomorphic determinants of landscape change in Australian rangelands? *Ecological Management and Restoration*, **4**, 180–186.

Pringle, H.J.R., Watson, I.W. and Tinley, K.L. (submitted to Landscape Ecology). Rangeland improvement or ongoing degradation - reconciling apparent contradictions from the arid rangelands of Western Australia.

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

Recher, H. F. and Lim, L. (1990). A review of the current ideas of the extinction, conservation and management of Australia's terrestrial vertebrate fauna. *Proceedings of the Ecological Society of Australia,* **16,** 287–301.

Richards, R., Watson, I., Bean, J., Maconochie, J., Clipperton, S., Beeston, G., Green, D. and Hacker, R. (2001). *The Aussie GRASS Southern Pastures Sub-project. Final Report to the Climate Variability in Agriculture Program.* Queensland Department of Natural Resources and Mines, Brisbane.

Taylor, L. (2002). *Developing an environmental management system. A practical guidebook for pastoralists.* Department of Agriculture Western Australia.

Thackway, R. and Creswell, I.D. (1995). (eds.). *An interim biogeographic regionalisation for Australia. A framework for setting priorities in the national reserves system cooperative program. Version 4.0.* Australian Nature Conservation Agency, Canberra.

Tinley, K. and Pringle, H. (2002). What is the EMU exercise? In: *Shifting Camp, Conference Proceedings of the 12th Biennial Conference of the Australian Rangeland Society* (eds. Nicolson, S. and Wilcox, D.), Kalgoorlie Western Australia, September 2002, 349–350.

Tongway, D. (1994). *Rangeland soil condition assessment manual*. CSIRO Division of Wildlife and Ecology, Australia. 69 pp.

Tongway, D. and Hindley, N. (1995). *Manual for assessment of soil condition for tropical grasslands*. CSIRO Division of Wildlife and Ecology, Australia. 60 pp.

URS (2004). *Final evaluation of the Gascoyne-Murchison Strategy. Prepared for Department of Agriculture and The Board, Gascoyne-Murchison Strategy.* URS Sustainable Development. http://www.gms.wa.gov.au/documents/GMS%20Final%20Evaluation%20Final%20Report%20v2.pdf

Vital Options Consulting (2004). *Ninghan Indigenous Protected Area Draft Plan of Management 2004*. Unpublished report by Vital Options Consulting.

Watson, I. (2003). Regional scale monitoring systems – making a case for causality. In: *Biodiversity monitoring in the rangelands: a way forward, Volume 1 on CD.* (eds; Smyth, A., James, C. and Whiteman, G.). Report to Environment Australia. Centre for Arid Zone Research, CSIRO Sustainable Ecosystems, Alice Springs, NT.

Watson, I., Blood, D., Novelly, P., Thomas, P. and Van Vreeswyk, S. (2001). *Rangeland monitoring, resource inventory, condition assessment and lease inspection activities in Western Australia conducted by the Department of Agriculture*. Report prepared for the National Land and Water Resources Audit, Canberra.

http://audit.ea.gov.au/ANRA/rangelands/rangelands_frame.cfm?region_type=WA&region_code=WA&info=monitoring

Watson. I. and Thomas, P. (2002). *The Western Australian Rangeland Monitoring System (WARMS) in the Gascoyne-Murchison Strategy area, including an assessment of recent changes to shrub populations*. Report prepared for the Regional Environmental Management Program of the GMS. 113 pp.

Watson, I. and Thomas, P. (2003). Monitoring shows improvement in Gascoyne – Murchison rangelands. *Range Management Newsletter*, **03/1**, 11–14

Watson, I.W., Westoby, M. and Holm, A.McR. (1997a) Demography of two shrub species from an arid grazed ecosystem in Western Australia, 1983–1993. *Journal of Ecology,* **85,** 815–832.

Watson, I.W., Westoby, M. and Holm, A.McR. (1997b). Continuous and episodic components of demographic change in arid zone shrubs: models of two *Eremophila* species from Western Australia compared with published data on other species. *Journal of Ecology,* **85,** 833–846.

Water and Rivers Commission (1997). *The State of the Northern Rivers.* Waters and Rivers Commission, Perth.