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Murraylands Region

A Landscape Assessment Framework: As applied to the Murray Mallee IBRA Sub-region

July 2010

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Glossary

Endogenous disturbance – a disturbance to which the system has been exposed repeatedly through evolutionary time (McIntyre and Hobbs 2000).

Exogenous disturbance – a disturbance novel to the system (McIntyre and Hobbs 2000).

Fragmented (landscape) – 10-30 % destroyed and/or mostly highly modified (McIntyre and Hobbs 1999; 2000).

Intact (landscape) – < 10 % destroyed and/or low levels of modification (McIntyre and Hobbs 1999; 2000).

Relictual (landscape) – >90 % destroyed and/or mostly highly modified (McIntyre and Hobbs 1999; 2000).

Systemic – system-wide, affecting a system, such as a landscape, as a whole.

Variegated (landscape) – 40-90 % destroyed and/or low-high levels of modification (McIntyre and Hobbs 1999; 2000).

Summary

This report presents the results of a Landscape Assessment undertaken for the Murray Mallee IBRA Sub-region. The primary objective of a Landscape Assessment is to identify ecosystems or ecological attributes of a landscape that should be prioritised for conservation activity. This prioritisation is justified through the fact that a range of species at risk are commonly associated with the ecological attribute, suggesting that some modification to that attribute is responsible for this common level of risk.

For the purposes of this assessment, the current status of groups of bird species (landscape response groups) was used to indicate the current function of ecosystems (defined by an ecological vegetation hierarchy) within the study area.

The following environmental settings were prioritised for restoration, based on the assessment:

- deep sand in the Holder landscape
- deep sand in the north of the Karoonda landscape
- calcrete ridges and plains in the south of the Karoonda landscape
- areas of shallow sand over Parilla sand (shallow sand over clayey sand, often on hillslopes in the south of the Karoonda landscape

In the immediate future, work should define conservation goals based on these priorities in conjunction with key stakeholders. Then, under an adaptive planning process, implement work to achieve those goals.

A further short-term priority is to improve the landscape assessment for the Sherlock landscape which is not currently well understood.

This landscape assessment framework will also be applied to a number of landscapes to the west of the River Murray (on the Western Murray Plains) in 2010-2011.

The Landscape Assessment Framework (LAF)

Landscape assessment – a brief summary

Across a range of spatial scales (global→regional), the extent of conservation issues requiring attention far exceed our current capacity to address them. There is a need, therefore, to prioritise conservation activity across these spatial extents.

In order to ensure that limited resources are used effectively, conservation requires planning. Ideally, such planning would be iterative and fit within an adaptive management framework. A key requirement of such planning is the establishment of clearly articulated goals, that underpin the identification, prioritisation, implementation and evaluation of conservation activities (Wilson *et al.* 2006; Bottrill *et al.* 2008).

In addition, there is now widespread acknowledgement that conservation goals need to be context-specific (Failing and Gregory 2003; Miller and Hobbs 2007; Hobbs 2008), such that the goals are designed to address the conservation requirements of a particular socio-ecological setting. The need for context in goal setting is important, not only from the perspective of effective biodiversity conservation, but also to allow managers and other stakeholders to identify with conservation goals that are relevant to 'their patch' and linked to tangible conservation outcomes.

However, landscape conservation goals are often defined poorly and in general terms. A common approach is to relate goals to generic surrogates for biodiversity. A variety of approaches to setting priorities for landscape conservation have been drawn upon, including prioritising areas of high species richness, diversity or endemism (Myers *et al.* 2000), or representativeness (Groves *et al.* 2002). Alternatively, general 'rules of thumb' based on ecological theory (such as the Theory of Island Biogeography; (MacArthur and Wilson 1967), are used to set 'habitat' (~native vegetation) area targets (e.g. 30% of pre-European cover). This is in spite of evidence that these generic targets fail to meet the area requirements of ecosystems in any specific context (Desmet and Cowling 2004). Generally, these approaches *presume* that prioritising conservation activity in areas that meet these umbrella criteria will meet the conservation requirements of most of the ecological components and processes of the landscape, including those that are most at risk of deleterious and potentially irreversible change. Rather than relying on this presumption, an alternative approach would be to directly target the conservation requirements of those components and processes that are at risk, to ensure a more direct link between these and the conservation activities required to sustain them. This requires an understanding of which ecological components or processes are at risk within a landscape. The Landscape Assessment Framework is designed to specifically identify these at-risk landscape components, and use these to design relevant conservation targets and activities for that landscape. Figure 1 shows where the Landscape Assessment fits within a generic planning cycle.

The Landscape Assessment Framework is specifically designed to provide information on the current state and historic trend of ecological components and processes within a landscape, and an understanding of the processes that led to these patterns. Through the collation and synthesis of this information for a landscape, conservation priorities can be set that target those components of the ecosystem that are most at risk of local (i.e. landscape) extinction (see below). Furthermore, conservation activity can then be designed to specifically meet these priority goals, and monitoring can be designed to test the effectiveness of these activities in achieving these specific goals.

In order to identify which ecological components of a landscape require priority conservation attention, three core pieces of information are required (also see Figure 1):

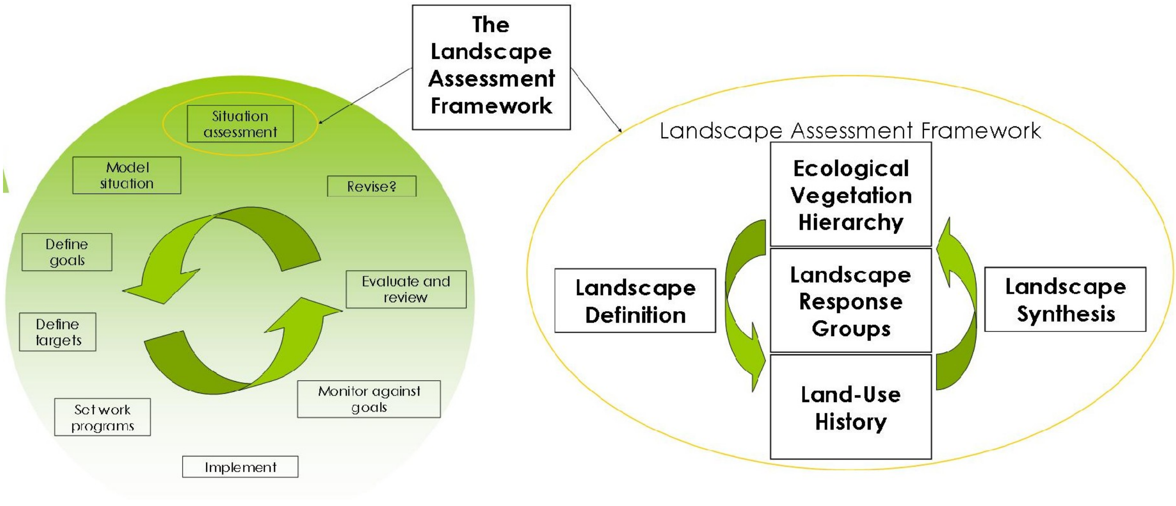
- an understanding of the relationships between biotic and abiotic components of an ecosystem, such as the relationships vegetation and the physical environment, or how species interact with their environment;
- an understanding of historic changes to ecological components within landscapes, through analyses of changes in the distribution and abundance of species that depend on these components;
- an understanding of land-use and environmental history for a landscape, that provides insight into the patterns observed in 1. and 2.

Fundamentally, Landscape Assessment combines information on historic species trends, with information on the ecological/conservation requirements of those species, to identify ecological components and processes that appear to be commonly associated with declining species. It is these components and processes that are then targeted for priority conservation activity, such that we are able to cover the systemic conservation issues affecting a range of species (rather than focussing on species-specific conservation activity).

Through the synthesis of these pieces of information, we can identify common ecological requirements of species that are undergoing similar historic trends (e.g. declining), and subsequently infer that their common trend is linked to these common requirements. This can then be used to identify those components or processes that appear to be linked to decline, and conservation activity can be designed to address these systemic issues.

Figure 1: The landscape assessment framework and it's context within a planning cycle

The figure on the left shows the Landscape Assessment Framework in the context of a broader adaptive planning process. The figure on the right shows the core components of the Landscape Assessment Framework.



LAF and threatened species

The LAF is not designed to encompass the needs of threatened species conservation planning. In some circumstances LAF may inform threatened species planning and may be informed by threatened species work, but the two are separate processes. Both are required to have any confidence that the biodiversity of an area is likely to be conserved.

Context within broader planning processes

SASP and No Species Loss

The Murray Mallee LAF also makes a significant contribution, in the Murray Mallee, to achieving the SASP (Government of South Australia 2007) target 3.1 Lose No Species, including the targets and recommendations in the *State Biodiversity Strategy for South Australia (DEH 2007)*. The LAF specifically meets or contributes to a number of targets (T) and recommendations (R) within that strategy:

- T3 – the marine and public and private terrestrial protected area systems are managed for biodiversity, whereby: 1) priorities and requirements for biodiversity management are determined, by 2008; 2) management programs are in place, by 2017
- T4 – threats to biodiversity are managed on terrestrial, aquatic and marine public and private lands, whereby: 1) significant threats are identified and objectives and priorities are set, by 2008; 2) the introduction and establishment of new threats is prevented, by 2007 (and ongoing); 3) threats that have the potential to become significant threats are eradicated or contained, by 2012; 4) significant existing threats are contained or suppressed, by 2017

- T5 – ecological restoration programs are implemented in areas critical to increasing ecological connectivity and maintaining communities, species and ecological processes, by 2012
- T6 – criteria for identifying species and ecological communities that are declining but are not yet threatened are established and baselines set, by 2010
- T8 – ecological communities and ecological processes that are currently declining are identified and targets for landscape restoration set, by 2011
- T11 – decline in species and ecological communities is halted, by 2017
- T23 – gaps in knowledge and priority areas for research on biodiversity and impacts on biodiversity are identified and appropriate research supported, by 2012
- T19 – landowner, industry, government and community stewardship for biodiversity is increased, whereby: 1) existing programs for engaging landowner, industry, government and community participation in biodiversity conservation are implemented, by 2007; 2) new and innovative mechanisms and incentives for engaging landowner, industry, government and community participation in biodiversity conservation programs, are developed and implemented, by 2010
- T20 – biodiversity networks for local and community organisations in biodiversity conservation that share information and knowledge, and further stimulate local engagement, are active, by 2008 (and ongoing)
- T30 – repeatable and ecologically defensible processes for defining and delivering integrated conservation and restoration targets across multiple spatial and temporal scales are developed and trialled by at least one NRM region, by 2010
- T34 – gaps in knowledge and priority areas for research and monitoring about climate change impacts on biodiversity are identified and appropriate research is supported, by 2012
- T36 – the potential for current ecological restoration programs to be adaptive to the impacts of climate change on biodiversity is assessed, and the potential for programs to be reconfigured so that they adapt to climate change is reviewed, by 2012
- T39 – the impacts of climate change on biodiversity (based on modelled predictions) are factored into ecological monitoring programs, and used to establish and revise management and climate change adjustment strategies, by 2017
- R4 – the capacity to model and predict the impacts of climate change on biodiversity are improved, by 2012

SAMDB NRM

LAF as applied to the Murray Mallee makes significant contributions to a number of the SAMDB NRM Board's Targets (which can be found at www.samdbnrm.sa.gov.au/Portals/7/AWMN/NRMPlan/Volume%203%20-%20Regulatory%20and%20Policy%20Framework.pdf), including:

- B1.1 Protect and manage priority remnant native ecosystems
- B1.2 Increase the extent of native ecosystems
- B1.3 Improve the condition of existing native ecosystems
- B1.4 Improve community appreciation of native ecosystems and species
- B3.2 Manage critical threats to threatened ecosystems
- P3.1 Effective communication and partnerships between NRM stakeholder organisations
- P3.2 Improve alignment of Local & State Govt, and Industry planning policy with NRM goals
- P4 Monitoring & Evaluation (outcome focussed).

LAF as applied to the Murray Mallee IBRA Sub-region

Murray Mallee Ecological Vegetation Hierarchy (EVH)

Geomorphology relevant to current environmental settings

The following section is based on a series of previous work, annotated here for interest:

- Potter et al (1973) – this work focuses specifically on the northern Mallee and western Murray Flats, including a readable summary of the environmental evolution of the area, including wider information where relevant, as a precursor to describing soils at a Land System scale. This is the original source of Land Systems for the northern part of the Murray Mallee, although there have been changes since this work.
- Brown (1988) – a precursor to the much more detailed 1991 work with Stephenson that provides a brief overview of geology relevant to the entire Murray Basin.
- Wasson (1989) – one of the earlier overall summaries of geology and geomorphology relevant to the entire Murray Basin
- Brown and Stephenson (1991) – by far the most detailed study of the geology of the entire Murray Basin.
- McCord (1995) – the companion to the earlier Potter et al work, this time focussing on the southern mallee. This is the most specifically relevant work for the South Australian Murray Mallee and the original source of the Land Systems for the southern mallee. McCord provides a readable summary of the environmental evolution of the southern mallee as a precursor to describing the soils at a Land System scale. The following section uses this work extensively.
- Bowler et al (2006) – a recent comprehensive study of the geology of the Murray Basin and the first to make extensive use of recent technologies, particularly digital elevation models.

The Murray Mallee IBRA Sub-region (Murray Mallee) is part of the Murray Basin, a 300,000 km^{2}, saucer-shaped, low-lying area of inland southeast Australia. For the last 65 million years the basin has alternated between marine and non-marine depending on the interaction between tectonics and sea level. Sediments from marine transgressions cover the bedrock of the basin. The important sediments for the current surface of the Murray Mallee began deposition about 5 million years ago with the coastal Loxton Sand – eroded from the forming Mount Lofty Ranges and deposited as the sea gradually retreated across the basin. Paralleling the current coastline are a series of ridges formed during this period as beach sands (similar to the current Coorong). The last of these ridges is the Marmon Jabuk Range. After the Loxton Sand, two spatially separated layers were formed through reworking of the Lowan Sand by wind and flowing water – the estuarine Northwest Bend Formation formed in the west of the basin against the Mount Lofty Ranges near the current Murray River and Parilla Sand formed in river and lake conditions to the east of the Northwest Bend Formation. In some minor areas of the Murray Mallee current soils have formed from the Loxton/Parilla Sands.

Around 1.5 million years ago a wetter period and tectonics combined to create a mega inland lake, or series of lakes referred to as Lake Bungunnia which covered much of the northern Murray Mallee (Stephenson 1986). This lake and it's sediments influence a large proportion of the current surface, mainly the heavier soils. The Blanchetown Clay was initially laid down throughout the lake but also in more southern areas not part of the lake around Pinnaroo (Blanchetown Clay equivalent). As the lake dried up, it formed a number of discontinuous lobes, two of which covered the northern part of the Murray Mallee. In only the western of these lobes the Bungunnia Limestone was deposited – forming the extensive sheet calcrete both sides of the River Murray and extending out to the east away from the river where it has been covered in places by more recent processes.

About 1 million years ago the sea advanced again as far as the Marmon Jabuk Range, eroding the Loxton/Parilla Sands and depositing the limestone Coomandook Formation. As the sea retreated it left a coastal plain and then the Bridgewater Formation – a series of beach dune systems with associated interdunal lagoons, each of which would have been similar to the current Coorong. On the coastal plain, a limestone layer developed, similar to and formed at the same time as, the Bungunnia Limestone.

During the various episodes of coastal dune building, strong southwesterly winds, an arid climate and exposed sea beds resulted in the deposition of a blanket of calcareous loess across the basin. The Woorinen Formation developed through the gradual accumulation of calcareous loess derived soils mixing with the underlying Loxton/Parilla Sand over the period from about 300,000 to 22,000 years ago, but there are also calcrete layers present in the mallee that are not related to the Woorinen Formation. The uppermost, current soil surface is sometimes referred to as the Loveday Soil. In the northern Murray Mallee the Woorinen Formation dominates the current landscapes. In the south, the Woorinen Formation is much less dominant in the current landscape, although remnants of various other calcrete layers remain important, often as high points in the landscape in contrast to the northern Murray Mallee where they occur as extensive swales and flats. At the same time the Woorinen Formation was accumulating in the north, in the south, from the Marmon Jabuk Range northeast to Karoonda significant erosion by water occurred, draining to either the Murray River or the coast but also depositing alluvial sediments on some ridges, slopes and swales. The dissection of the southern areas left it susceptible to further wind erosion, added to by rapid climate fluctuations during this period which presumably deteriorated the vegetation cover.

Over the most recent glacial period, about 22,000 to 18,000 years ago, the Woorinen Formation was worked into the east-west parallel dune system which characterises the surface today. However, in the south, the Loxton/Parilla Sand and Bridgewater Formation – the two forms of ancient, coastal dune systems – were eroded into the pale yellow and white dunes of the Lowan Sand (also known as Molineaux Sand). At times, this erosion occurred as mega-blowouts, creating deep, loose sand dunefields migrating from west to east across the landscape – today recognisable as the Little, Big and Sunset Deserts and associated areas of South Australia (Ngarkat and Billiatt). At the same time, similar processes were eroding the Bunyip Sand from the Murray River valley, creating the 'fingers' of parabolic and irregular dune systems that are interspersed with the shallow calcrete of the Bungunnia Limestone to the east of the Murray River.

Environmental Settings

The geomorphology outlined in the previous section translates into a number of different environmental settings, summarised as:

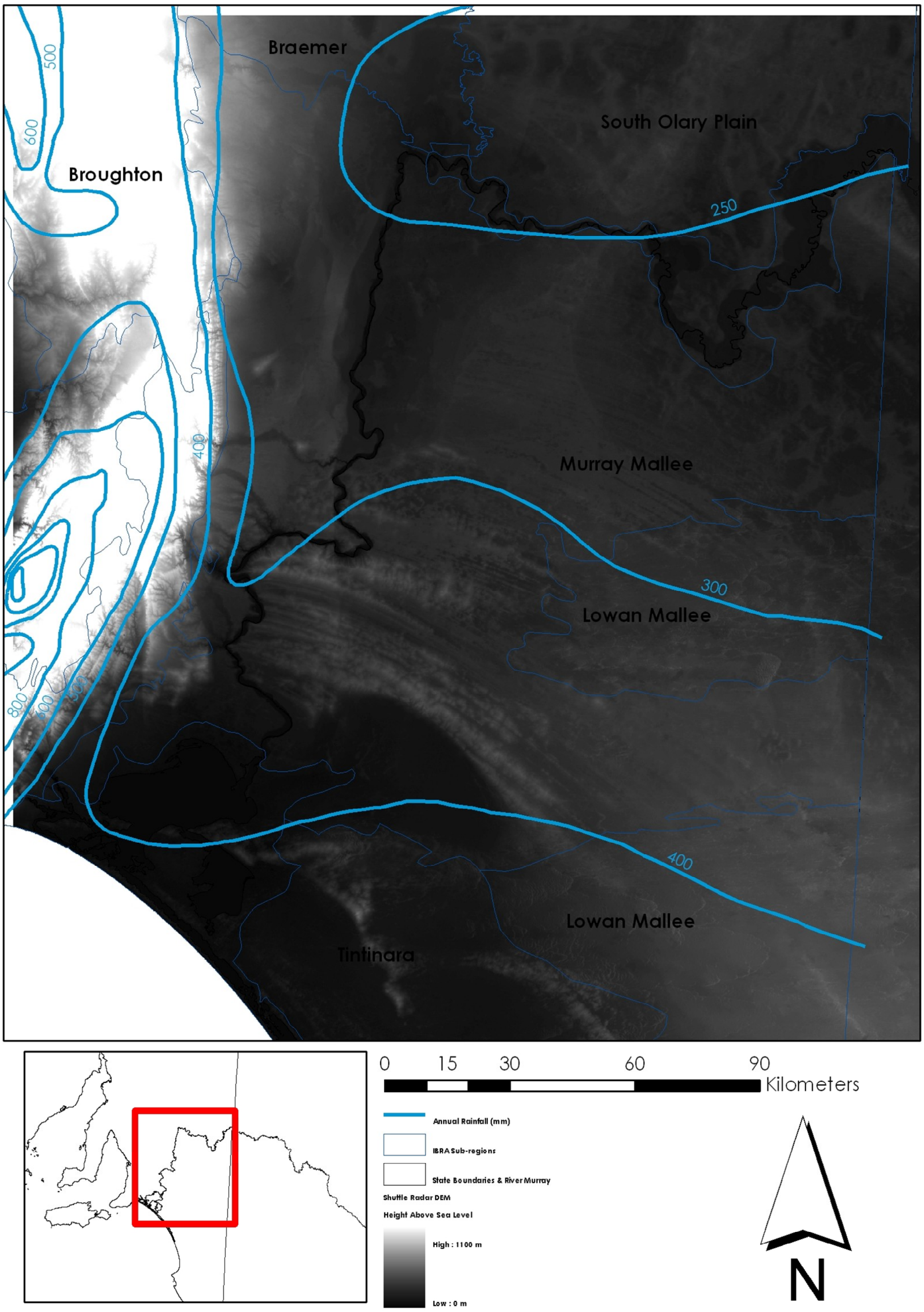
- Loose, deep sand – generally Lowan Sands
- Shallow sand over consolidated dunes – Woorinen Formation
- Shallow sandy loams over rubbly calcrete – Calcrete, sometimes as part of the Woorinen Formation
- Very shallow sandy loams over sheet calcrete – Bungunnia Limestone
- Clayey sand– with or without loam developed directly on Loxton/Parilla Sand
- Clay soils as plains or depressions – with or without loam developed directly on Blanchetown Clay or equivalent

These soils form the basic units that interact and repeat at various scales across the region to define the different landscapes.

Climate

Besides soil, the other key environmental determinant of vegetation in the mallee is climate (White 2006). The Murray Mallee is low and relatively flat, leading to subtle, long-distance gradients compared to surrounding areas (Figure 2). While generally the climate gradient runs from southwest to northeast, the gradient becomes more north-south further east within the state. Temperature and variability of rainfall follow a similar gradient, increasing from southwest to northeast. The rainfall gradient also runs from 'temperate' to 'semi-arid' across the Murray Mallee.

Figure 2: Annual rainfall (mm) and regional topography



Vegetation types

The interaction of climate and soils/topography drive the different vegetation types that occur across the Murray Mallee. A series of authors have recognised and summarised the interactive effects. Noy-Meir (1974) analysed vegetation site data over a large area of the lower Murray-Darling Basin and found that the best environmental correlates of vegetation type were the distribution of soil moisture between shallow and deep layers, and between easily available and marginal moisture. Sparrow (1989; 1991) examined vegetation site data from across South Australia, focussing on the mallee component for one study (Sparrow 1989). Again, the relationship of vegetation type and soil water relations was highlighted as important, with a simple model generated to explain observed response of various eucalypt species to gradients of sand depth and rainfall. Besides the eucalypts for which the model is presented, Sparrow also noted similar responses from shrub and other understorey species. As each plant species responds to the different climate gradients according to its own preferences, the result is continuous, rather than abrupt, change vegetation types and the mallee resists classification into vegetation communities more than other vegetation types (Noy-Meir 1974; Sparrow 1990; White 2006). While not explicitly correlated with rainfall, the same gradient in dominant eucalypt overstorey can be discerned within the vegetation types described by a vegetation survey of the Murray Mallee in 1990 (Foulkes and Gillen 2000), the dominant eucalypt overstorey species on dunes changes from *Eucalyptus incrassata*, to *E. dumosa*, then *E. cyanophylla* moving from southwest to northeast down the rainfall gradient. In 2003 the results of a major vegetation study in northwest Victoria was published, further improving the understanding of vegetation types and their environmental drivers in mallee areas (White et al. 2003). This study did not include data from South Australia, but the understanding can be extended to the Murray Mallee, particularly with later conceptual refinement and consolidation (White 2006).

The results of all the above studies concur that soil texture is a primary driver of the structural aspects of vegetation types in the mallee, with position along a climate gradient a primary driver of the specific floristics found at a site. Heavier soils, so productive in temperate areas, are less productive in the semi-arid mallee areas due to relatively poor water relations, leaving these areas generally as open grassy woodlands. The lighter soils are generally more productive due to their better water relations caused by three main properties: capacity, permeability, and water potential (Noy-Meir 1974). Better capacity allows lighter (coarser grained) soil to hold more water, preventing water from pooling on the surface, and it also therefore allows any amount of rain to move further into the soil profile. Permeability enables more water to find its way into the soil profile, rather than to run off. As the soils dry out, plants are able to access the water in coarse grained (less clay content) more easily due to the effect of clay particles on water potential – clay soils tend to hold the small amounts of remaining water much tighter than the lighter soils which will give up the water more easily, thus making it available to plants. Noy-Meir (1973) termed the better soil water relations of lighter soils in semi-arid and arid areas, and their consequent productivity, the ‘inverse texture effect’ because of the contrast with temperate areas in which heavier soils are usually the more productive (when alternative resources become the factors limiting plant growth). The lighter soils in semi-arid mallee generally support either a dense *Triodia* understorey or a patchily dense shrub layer.

Key Vegetation Processes

While the interaction of climate and soil determine the environmental settings in which the vegetation types develop, a number of processes are also important in determining the structure and floristics that develop on a particular patch of each environmental setting. Understanding both endogenous and exogenous processes that lead to the development of a certain vegetation type are particularly important when implementing management against a landscape restoration goal. Documenting this information in the form of a state-and-transition model (see Westoby et al. 1989; Suding et al. 2004) should guide management more effectively and highlight key gaps in management knowledge. Currently, a state-and-transition model is being developed for the Deep Sand environmental setting in the northern Murray Mallee, but models are lacking for other settings within the mallee.

Fire is the dominant endogenous disturbance in the mallee. It forms a major component of most models of recruitment in mallee (Wellington and Noble 1985a; Bradstock 1989; Noble 1989; Bishop 1990; Bradstock et al. 1995; Cohn and Bradstock 2000), and hence in the ability of plants to survive and adapt to their environment. However, changes to the endogenous fire regime are likely to have impacted the vegetation types of the mallee, as different fire regimes have been shown to alter the composition and structure of mallee vegetation (Bradstock 1989). The importance of fire, is due to its effect on soil water relations – fire changes the availability of water to plants. In established mallee communities, most water is transpired by the established plants, causing water shortage to recruiting plants without well established roots during times of year when water is limiting, (Wellington and Noble 1985b; Bradstock 1989; Wellington 1989; Dalton 1992; Barron et al. 1996; Cohn and Bradstock 2000), whereas after a fire the leaf area through which water is lost through evapotranspiration is reduced dramatically, leaving much more water available in the soil profile for establishing plants (Specht et al. 1958; Bradstock 1989; Wellington 1989).

Grazing (and browsing) are the other important processes in determining Murray Mallee vegetation types. Many of the original grazers of the Murray Mallee are now extinct (e.g. pig-footed bandicoot, western barred bandicoot, bridled nail-tail wallaby, lesser stick-nest rat) (diet, distribution and status from Bennett et al. 1989). Grazing pressure is now exerted by a range of introduced and native increaser species, a change to the endogenous grazing regime. Grazing pressure can influence the composition of communities regenerating after fire (Cohn and Bradstock 2000), but appears to be also dependent on the rainfall over a larger area. When rainfall is good before and after a fire, grazers (mostly kangaroos) are less likely to congregate on the recent fire (Caughley et al. 1985) – again, fire, water availability and grazing appear as the dominant processes of the mallee system.

Various models have been proposed linking these key processes with vegetation type and landform. Key amongst these is the work of Bradstock (1989) in which dominance of key species is related to fire regime, in sandy environmental settings. This model suggests that mallee/shrub, mallee/*Triodia* and *Callitris* states are possible for sandy settings, depending on fire history.

In the heavier soils, fire is reduced in importance and models relating vegetation type to processes have focussed on the interaction of grazing and fire – although the emphasis of these models has been on keeping them productive for grazing. Few of these studies have really focussed on true mallee areas, although there are almost certainly some lessons for mallee ecology on heavier soils (e.g. Hodgkinson and Harrington 1985; Hodgkinson 1991; Hodgkinson 1992; Daly and Hodgkinson 1996; Noble et al. 2007a). A lack of directly relevant ecological information makes it difficult to interpret some of the heavier soil vegetation types. For example, the very, very open understorey in much of swales in the northern Murray Mallee could be a natural state, or a state derived by early pastoralism, elevated total grazing pressure and past events such as the rabbit plague of the late 1800s, or some combination. Another poorly understood heavier soil environmental setting is the heavier soil grassy mallee woodland between Ngarkat and Billiatt.

Other important processes

Besides these key ecological processes, there are a plethora of other processes and changes to processes that either keep mallee vegetation healthy or have been implicated in its degradation, but have not, or are rarely, explicitly considered in restoration. Nutrient cycling, water retention and stabilisation at the patch scale are particularly important in arid and semi-arid environments (Tongway and Hindley 2004). Yen et al. (2006) consider the particular importance of a range of social insects in mallee ecological processes, including decomposition by termites, seed dispersal and nutrient movement (e.g. from canopy to ground) by ants and pollination by native bees. More recently, the role of the suite of extinct mammals is receiving increasing attention for the key roles they play in semi-arid systems (e.g. Noble et al. 2007a; Noble et al. 2007b),facilitated by increased ability to study these species, and their role in ecosystems, in ‘natural’ settings such as the Arid Recovery area near Roxby Downs in South Australia and the Scotia Sanctuary in New South Wales. Lessons from these areas will no doubt be increasingly important in habitat restoration for conservation outcomes in semi-arid areas including mallee.

Murray Mallee Bird Landscape Response Groups

At the scale of a landscape, relatively discrete groups of species can be recognised, each associated more closely with certain vegetation types within that landscape. These groups should not be seen literally as the discrete units in which they are described. Reality is much more complicated, with each species (and, really, each individual) responding uniquely to a range of gradients, processes and historic events. However, as a gross model of the landscape, the groups do work adequately for this purpose.

In selecting species to include in each group, the following attributes were desirable:

- Historically present, or likely to have been present, throughout the Murray Mallee
- Individuals are mostly locally resident, or mobile at a scale probably less than 'landscape', but certainly less than region
- Local ecology understood well enough to be confident in associating with a particular habitat

Habitat is used here in the sense of vegetation type, as described in the EVH sections of this document.

The species used for each group are given in Table 1, including the number of records of each species made in each landscape.

Shrubs

Birds closely associated with habitats that contain shrubs that are at least patchily dense include:

- Inland Thornbill
- Purple-gaped Honeyeater
- Shy Heathwren
- Southern Scrub-robin

Woodland

Birds closely associated with habitats that have an open ground layer that may be grassy, have occasional low shrubs or bare:

- Brown Treecreeper
- Hooded Robin
- Jacky Winter

- Restless Flycatcher

Triodia

Birds closely associated with habitats that are dominated by *Triodia* in the understorey:

- Black-eared Miner
- Mallee Emu-wren
- Red-lored Whistler
- Striated Grasswren

Generalist

Birds that are not closely associated with only one habitat:

- Chestnut Quailthrush
- Crested Bellbird
- Malleefowl
- Variegated Fairy-wren

Agricultural Increaser

Birds that are associated with scrub surrounded by agricultural land:

- Australian Magpie
- Blue Bonnet
- Crested Pigeon
- Galah

In each of the LRG figures throughout this document, these are the species that are considered, although there are certainly more that could be included in each group. Future LAF iterations may consider other groups – it would be good to use plants to generate LRGs.

Table 1: Murray Mallee Landscape Response Groups – species and records within various landscapes

Effort is different between landscapes. These data are summarised only from repeated, standardised surveys. There have been no repeated, standardised surveys in the Sherlock landscape.

Murray Mallee Landscape Response Group	Common Name	Species	Landscapes				
			Billiatt	Holder	Karoonda	Loxton	Pinnaroo
Agricultural Increaser	Australian Magpie	*Cracticus tibicen*	23	87	51	16	11
	Blue Bonnet	*Northiella haematogaster*	1	9	13	12	5
	Crested Pigeon	*Ocyphaps lophotes*	2	27	25	18	7
	Galah	*Eolophus roseicapillus*	28	75	44	15	9
Generalist	Chestnut Quail-thrush	*Cinclosoma castanotum*	19	32	14		1
	Crested Bellbird	*Oreoica gutturalis*	17	37	11	1	1
	Malleefowl	*Leipoa ocellata*	12	11	16		
	Variegated Fairy-wren	*Malurus lamberti*	15	24	22	1	5
Shrubs	Inland Thornbill	*Acanthiza apicalis*	44	5	11		3
	Purple-gaped Honeyeater	*Lichenostomus cratitius*	19	6	22		3
	Shy Hylacola	*Hylacola cauta*	25	3	16		1
	Southern Scrub-robin	*Drymodes brunneopygia*	23	8	29		3
Triodia	Red-lored Whistler	*Pachycephala rufogularis*	6				
	Striated Grasswren	*Amytornis striatus*	7				
Woodland	Brown Treecreeper	*Climacteris picumnus*	26	1	6		
	Hooded Robin	*Melanodryas cucullata*	4	18	10	4	3
	Jacky Winter	*Microeca fascinans*	12	64	21	2	
	Restless Flycatcher	*Myiagra inquieta*	2	14	3	3	2

Murray Mallee Land-use History

It is more than likely that Aboriginal people lived in the Murray Mallee for over 40000 years. Aboriginal custodianship of the land, probably had a significant influence on the ecology of the Murray Mallee. The open plains occasionally present within the mallee vegetation are perhaps one of the most noticeable manifestations of this land management, with some evidence suggesting that in the absence of regular firing the open plains were invaded by woody *Acacia* species (Harris 1968; 1970). It appears likely that Aboriginal people were resident in the Murray mallee up until just prior to European interest in the area. However, they were severely impacted by diseases to which they had not been previously exposed, even in areas without direct European contact, as well as inter-tribal conflict and occasional terrible treatment by Europeans (Harris 1970; Hill 1981; Harris 1990; Kloeden et al. 1998; Foulkes and Gillen 2000).

The pastoralists moved into the mallee from the 1850s. Originally using the river as a water source, penetration deeper into the Murray Mallee was only enabled by the digging of wells, with a line of wells being established from Nildottie (well), to Bakara, Eastern and Elizabeth (Kloeden et al. 1998). These wells also provided hubs for the transport route through the mallee that was only surpassed when the railways were built.

With the decrease in Aboriginal custodianship and the increase in grazing during the 1850s-1890s the scrub 'thickened up' in many places, reducing the value of the land for grazing. According to oral tradition, the grazing, combined with pastoralists regularly burning in an attempt to promote grasses, favoured the growth of a denser shrub layer that in turn prevented the growth of grasses necessary as feed for sheep. The final nail in the coffin of the early pastoralists was the coming of the rabbit in about the 1880s, combined with a drought in the mid 1880s. It was no longer economical to graze sheep with the thickening up of the shrub layer and rabbits removing all vegetation within their reach (Jones 1981; 1986; Matthew and Croft 2000).

Most pastoral leases in the Murray Mallee were given up by the early – mid 1890s. The Murray Mallee was unique in South Australia with regards the pastoralists leaving the land. In other areas of the state, the pastoral leases had to be terminated before expiry to enable the survey of the land for sale as farms (Williams 1974; Jones 1986). Short as it was, the pastoral era apparently saw some large changes to the landscape, including the extinction of one third of the mammal species (Bennett et al. 1989; Morton 1990). Further, if results from other systems in which grazing and fire are the dominant ecological processes, the mallee had probably been altered to an alternative state in which shrubs dominated at the expense of grasses in the understorey (Westoby et al. 1989), as suggested by early reports (Jones 1986). The combination of these changes, drought and the marginal nature of much of the country demonstrated by the mid 1890s at the latest that the mallee was not really viable pastoral country (Kloeden et al. 1998).

For the next 15 years or so, there was no direct human influence on the management of the Murray Mallee. There are no records of the response of the mallee to this removal of stock grazing pressure and decreased burning.

Agricultural settlement of the Murray Mallee occurred only after the limits of agriculture were reached in the north of the state – where many settlers plans were seriously curtailed by the a drought from 1880-1883 and their subsequent realisation that any previous good years were exceptional rather than the norm (Williams 1974).

Improvements in technology also enabled settling of mallee areas previously considered undesirable by the early settlers. Up until the late 1860s the only way to clear mallee was by hand. After that time, relatively efficient methods of rolling the scrub were invented (Williams 1974). Secondly, after about 1890, good proof that the fertility of the soils was improved greatly by the addition of superphosphate fertiliser enabled country previously deemed too marginal to be turned into agricultural land (Williams 1974; Jones 1986). The final barrier was transport, and with increasing coverage of railways, the Murray Mallee became increasingly viable agricultural land. The railways were stared in the southern mallee in 1906 and covered most of the Murray Mallee by 1914 (Pinnaroo Historical Society 1983; Jones 1986). Along with these major barriers, other continual increases in knowledge and technology improved the ability to farm increasingly marginal agricultural land, including the stump-jump plough, fallowing, and improved varieties of wheat (Williams 1974).

The combination of these improvements, slowly improving optimism after the 1880-1883 drought and the loss of farmers to new areas being opened up in Victoria, saw pressure to open up more areas for settlement, with the Murray Mallee being one of the few large areas in the agricultural areas of the state left to 'open up' (Williams 1974). This led, after considerable parliamentary debate (over 11 years: Kloeden et al. 1998), to the opening of the Pinnaroo railway in 1906 and a very quick settlement and cultivation of the land around Pinnaroo and Lameroo – by 1908 all land within 10 miles of the railway was taken up (Williams 1974; Jones 1981; 1986; Kloeden et al. 1998). On the back of this success, less concern was voiced at government investment in railways to 'open up' the rest of the Murray Mallee between the Pinnaroo railway and the River (Williams 1974; Kloeden et al. 1998)

In 1909 commissioners left on an inspection of the country between the Tailem Bend to Pinnaroo railway and the Murray River. They took evidence from farmers who had been growing wheat near Loxton from as early as 1895, and presented a report in July 1909 suggesting there was good land in the area between the Pinnaroo line and the river. The new 'Brown's Well Line' was started in November 1911 and was completed to Meribah by April 1913. An extension to Paringa was opened in October 1913 (Jones 1986, Chapter 4; Matthew and Croft 2000). Moving grain to the railway was a difficult task given the unmade and sandy nature of many of the roads, limiting the distance away from a railway that a farm was economically viable. About 5 miles appears to have been about the distance away from a railway a settler could hope to farm the land economically (Jones 1986). Extensions to the Brown's well railway were therefore necessary to allow the 'opening up' of more areas of mallee, including Karoonda to Waikerie (complete in December 1914), Karoonda to Peebinga (completed in

December 1914) (Jones 1986, Chapter 19), Alawoona to Loxton (in 1914) (Kloeden et al. 1998) and Wanbi to Yinkanie (complete line opened September 1925) (Jones 1986, Chapter 33).

Early in the 20th Century, mallee clearing was generally done by a process known as 'mullenizing' in which the mallee was broken off at ground level using horses and either a big log or a boiler. Axes were used to free up stubborn branches or trees. Once rolled the scrub was left to dry before burning (Williams 1974). The new settlers placed a lot of emphasis on getting a 'good' burn, as a bad burn left the area covered in unburnt or partly burnt sticks which had to be manually cleared. A good burn left the area covered in ash, but the ground clear of obstacles. Conditions for a good burn were suggested to be dry scrub, high temperature with a good wind blowing from the same directions all day (Williams 1974; Jones 1986). Killing the mallee stumps was a longer process, requiring slashing of regrowth – generally done about October every year for several years. The stumps also provided a very bumpy ride for the first few years of cropping. Each year, more and more stumps would be loosened up, and these were a potential source of further income, depending, again, on the distance to the railway. It could take up to ten years before the cleared areas were mostly free of mallee stumps (Jones 1986). The Murray Mallee settlers were able to capitalise on some decades of experience gained clearing mallee scrub throughout the rest of South Australia. Due to the difficulties in clearing, many farmers cleared less than was required by the terms of their lease (Williams 1974). While the soil lost its natural fertility very quickly, the initial crops after clearing had relatively high yields. 'A yield half that would be normal from then onwards (Jones 1986, p. 40)'. By the 1910s the use of superphosphate had become normal farming practice (Jones 1986).

Despite the efforts of the farmers at clearing during this period, in two peak periods of clearing (1907-1914 and 1925-1929) 32% of the northern mallee was cleared (counties of Albert and Alfred) and 31% of the southern mallee was cleared (counties Buccleuch and Chandos) (data from Williams 1974 and BDBSA egisdata layer ADMIN.hundreds), leaving the landscape still a variegated one.

According to Kloeden et al. (1998), it was a condition of agreement to purchase the land that typically one eighth of land had to be cleared in the first three years of settlement, and then one eighth per year after that until three quarters of the land was 'clear and cultivatable'. Based on that model, 25% remnancy would have been achieved only 8 years after settlement (about 1922 in the northern Murray mallee, and 1914 in the southern Murray mallee), and the vegetation cover would then have remained at that level. Based on the figures above and those presented later, it appears unlikely that this level of clearing actually occurred.

An important aspect of clearing, even from an early time, is that the most productive areas, and those easiest to clear were targeted first. Therefore, certain landscape elements were removed from the landscape earlier than others. For example, areas known today as ‘plains’ were usually open grassy areas in the past. These were sought out by the early Europeans, both for grazing and farming and hence disappeared functionally from the landscape quickly. Loss of these landscape elements on productive soils created a novel disturbance for many species that had previously relied, at least seasonally, on the productivity of these systems. A reliance on different landscape elements at different times of year has been demonstrated for a number of Australian systems, particularly for birds, which are mobile enough to move around the landscape exploiting the best resources at any one time (Keast 1968; Ford et al. 1993; Mac Nally and McGoldrick 1997; Paton et al. 1999; Mac Nally and Horrocks 2000; Paton 2000; Ford et al. 2001; Paton et al. 2004).

By the 1920s, mullenizing was being replaced by ‘logging’, where a log was dragged through the scrub enabling many of the roots to be levered up immediately, without breaking them (Williams 1974). Logging was replaced by chaining by the middle 1940s with the increasing use of tractors. Both logging and chaining reduced the need to grub out the mallee roots after the initial clearing, with roots being more often levered out of the ground on the first clearing run. Broadacre clearance of mallee vegetation continued until the 1980s when the first native vegetation clearance laws were established.

From the very start of mallee farming, non-farming sources of income were necessary to enable some mallee farmers to make ends meet. Perhaps the most important source of alternative income has been firewood (Williams 1974). Other sources of income relied on at times by mallee farmers including charcoal burning, eggs, brush-cutting, dairy products and pigs (Jones 1981; 1986). Today, there are a number of further ‘alternative’ sources of income generation being discussed as possibilities for the Murray Mallee, including farm forestry, perennial pastures, carbon sequestration, biomass production for renewable energy, oil and activated charcoal, and tourism (Murray Mallee LAP 2001; Bryan et al. 2005).

While problems with farming the mallee were identified very early on (particularly erosion risks) widespread improvements in land management probably only started by the 1960s following research at the Wanbi Research Centre. By the 1980s-1990s, vegetation clearance regulation, myxomatosis, continually improving farming practices, rabbit calicivirus disease and then significant government investment (Natural Heritage Trust, Natural Resource Management and Caring for Our Country) created conditions where many of the processes causing ongoing degradation were alleviated. There has also been increasing interest from landowners in managing their scrub, with a range of information becoming available (e.g. Barratt et al. 1991; EAC - Ecological Evaluation 2005). Combined, these changes may have seen improvements in the condition of remaining patches of vegetation, with data collected during 2006 in the northern Murray Mallee apparently supporting that view (Willoughby 2008). However, these improvements are all patch-related, with no improvements targeting landscape scale processes which will continue to pressure remnant vegetation, particularly in the most cleared areas (Cale and Willoughby 2009).

Murray Mallee Landscapes

Each landscape described here is based on one or more Land Systems (Potter et al. 1973; McCord 1995). Land Systems have been lumped together where their environmental settings are similar and they co-occur within the region. The final filter for lumping Land Systems to landscapes was cultural, heavily cleared Land Systems are not lumped with less cleared Land Systems. The name used for each landscape is that of the most well known Land System (i.e. a subjective decision was made by the author). The list of Land Systems that intersect the Murray Mallee IBRA Sub-region boundary are provided in Appendix 1.

The landscapes can be summarised as:

- Billiatt and Ngarkat (Lowan Mallee IBRA Sub-region) are dominated by Lowan Sands with isolated patches of clay
- Holder and Sherlock are undulating plains of shallow soils with significant calcrete development in the soil profile with sand occurring as dunes scattered through the landscape
- Karoonda contains a mixture of the calcrete, clay, sand and Parilla Sand present within the other landscapes
- Pinnaroo is the 'reverse' of Billiatt and Ngarkat, being predominantly an undulating plain of clay flats with areas of sand scattered throughout
- Murbko and Murtho are both small and discontinuous landscapes. Murbko is most similar to Billiatt and Ngarkat, being generally covered in deep, aeolian sand. Murtho is quite similar to Loxton
- Loxton is similar to Sherlock and Holder, but has deeper sandy loam over the calcrete and has areas where the saline groundwater intersects the surface (Noora Land System)

The combination of geomorphology, land-use history and location along climate gradients has translated into a wide range of remaining native vegetation cover (Table 2).

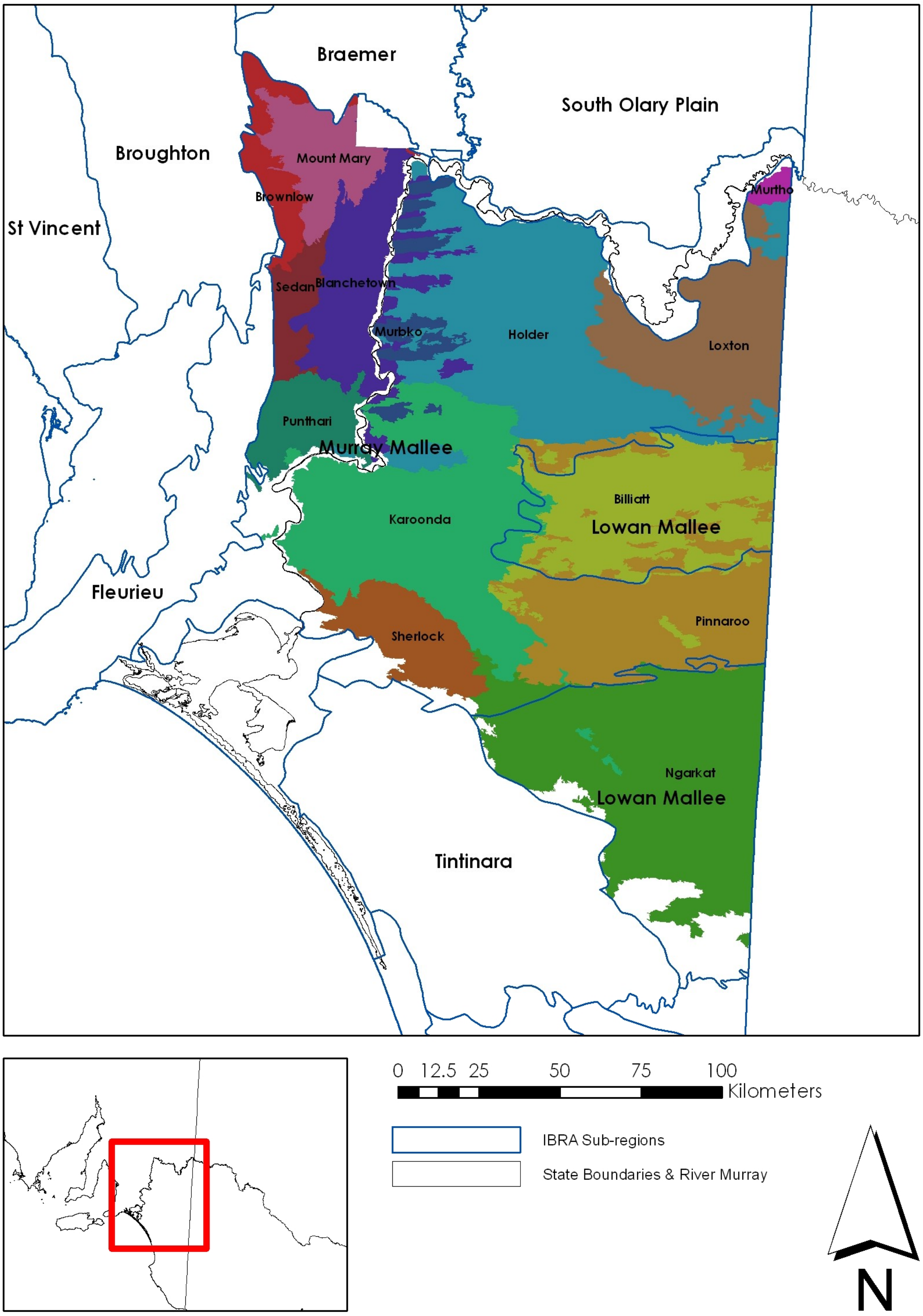
Table 2: Vegetation cover statistics for Murray Mallee landscapes

All spatial data from BDBSA – EGIS. Landscape boundaries generated from LANDSCAPE.SoilLandscapeUnits and vegetation cover from VEGETATION.NativeVegetationCover. Access date 30/06/2010. Landscape boundaries are based on the Land System mapping, (Potter et al. 1973; McCord 1995), modified as documented in this report.

IBRA Sub-region	Landscape	Area (hectares)	Vegetation Cover (hectares)	Remnancy	McIntyre & Hobbs (1999; 2000) categorisation
Lowan Mallee	Billiatt	253000	130000	52%	Fragmented
	Ngarkat	457000	281000	61%	Variegated
Murray Mallee	Blanchetown	167000	122000	73%	Variegated
	Brownlow	59000	23000	39%	Fragmented
	Holder	440000	103000	24%	Fragmented
	Karoonda	401000	29000	7%	Relictual
	Loxton	204000	11000	5%	Relictual
	Mount Mary	91000	68000	74%	Variegated
	Murbko	47000	11000	23%	Fragmented
	Murtho	11000	3000	31%	Fragmented
	Pinnaroo	306000	11000	4%	Relictual
	Punthari	75000	9000	12%	Fragmented
	Sedan	46000	8000	17%	Fragmented
	Sherlock	97000	6000	6%	Relictual

Figure 3: Landscapes of the Murray Mallee, as described in this version of the Murray Mallee LAF

All spatial data from BDBSA – EGIS. Landscape boundaries generated from LANDSCAPE.SoilLandscapeUnits. Access date 30/06/2010. Landscape boundaries are based on the Land System mapping (Potter et al. 1973; McCord 1995), modified as documented in this report.



Pinnaroo Landscape

The Pinnaroo landscape includes the Pinnaroo, Allenby, Bews, Gurrai and Lameroo Land Systems (McCord 1995). There are outliers of this landscape north of the Billiatt landscape – particularly the Halidon Land System. The values of these areas should probably be considered with respect to their location within the region, rather than as part of the Pinnaroo landscape. As Billiatt and Pinnaroo are landscapes at opposite ends of a continuum from clay dominated to sand dominated, Halidon is probably best considered with Billiatt, as part of the continuum, rather than its other neighbouring landscape, Holder which is calcrete dominated. Annual rainfall is between 350 and 400 mm.

EVH (Pinnaroo)

The Pinnaroo landscape consists of gently undulating clayey plains with sandhills and sandplains occupying between 10 and 60% of the landscape. Characteristically, the heavier soils areas supported an open mallee grassland vegetation type while the sandhills and sandplains supported a mallee shrubland.

Due to the larger proportion of the landscape being characteristically open, fire would have been less of an influence on the Pinnaroo landscape than the neighbouring Lowan landscapes of Billiatt and Ngarkat. This may have led to floristically similar, but structurally different, Lowan Sand vegetation types in the two landscape types (White 2006).

Figure 4: Simple profile of Pinnaroo landscape

Modified from McCord (1995). Not to scale.

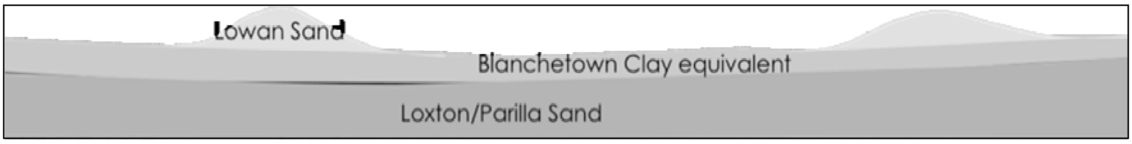


Table 3: Characteristics of Pinnaroo environmental settings

Modified from White et al. (2003) and Heard (2009). *E. – Eucalyptus. A – Acacia.*

Attributes	Lowan Sand	Blanchetown Clay equivalent
Structure	Mallee shrubland	Open Mallee grassland
Overstorey	*E. incrassata, E. leptophylla, E. arenacea* (in the south)	*E. dumosa, E. calycogona, Allocasuarina luehmannii, Callitris gracilis*?
Mid & understorey		
Ground layer	Sparse with sedges	*Lomandra effusa* and tussock grasses. Varied inter-tussock herbs
Notes	Due to the lesser influence of fire on this environmental setting (due to its landscape context), *Callitris* woodland may have been more common here than mallee	

LRG (Pinnaroo)

The eight sites at which repeated bird surveys occurred in spring 2009, revealed that the Shrub and Woodland LRG were still present, although the Agricultural Increaser LRG was the most ubiquitous Figure 5. None of the Generalist or *Triodia* LRG were found during repeat visit surveys in 2009. Surprisingly, the Woodland LRG remains relatively frequently encountered within the preferentially cleared clay flats, in fact Pinnaroo had the highest mean proportion of the Woodland LRG present within sites in the appropriate environmental setting (although there were only four sites in this setting). The Shrub LRG, while restricted to the larger patches of vegetation on Deep Sand, also remains.

Figure 6 shows the distribution of the LRGs in the Pinnaroo landscape. The Woodland LRG is still encountered where native vegetation remains with the exception of the Brown Treecreeper, which has no records from the Pinnaroo landscape. The *Triodia* LRG is no longer recorded – the two records indicated between 1990 and 2000 have location details of Lameroo and Pinnaroo but the records note collections were made outside of the Pinnaroo landscape. The Shrubby and Generalist LRG are still present within the landscape, although more readily encountered on or near larger patches of native vegetation, where sand locally forms a larger percent of the landscape. These few remaining larger patches are usually towards the west end of the Pinnaroo landscape, in the Lameroo Land System. The Agricultural Increaser LRG is widespread across the landscape and ubiquitous in native vegetation.

Figure 5: Mean proportion of LRG species present at sites within each environmental setting in the Pinnaroo landscape

Error bars are standard error, with sample sizes as follows; Deep (Lowan) Sand - south: 5 sites, Blanchetown Clay: 3 sites

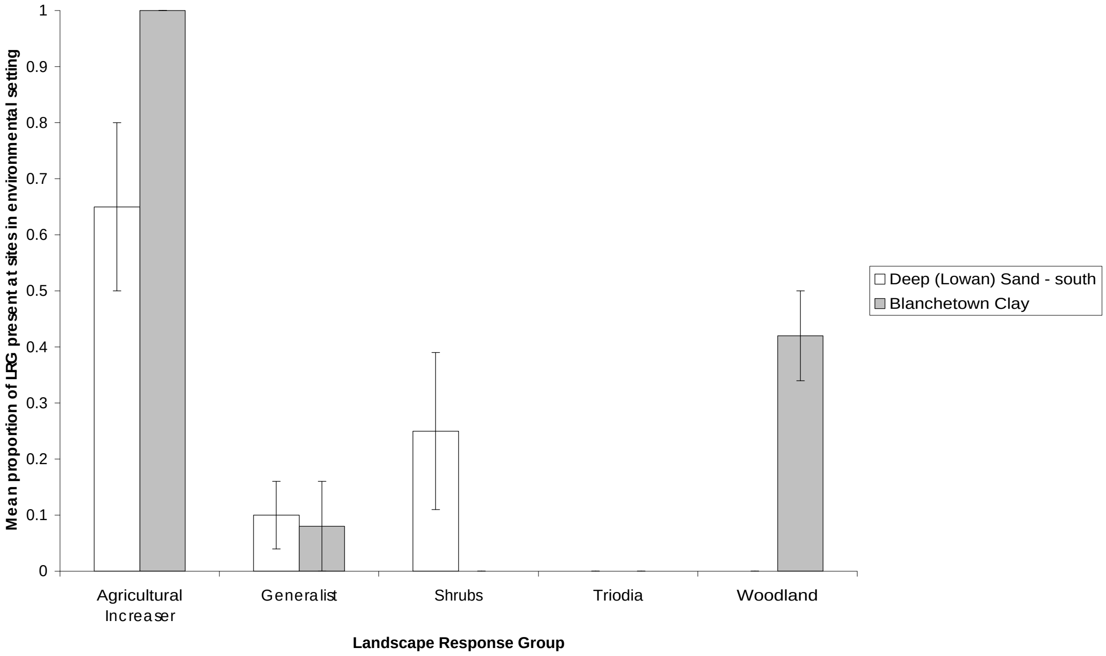
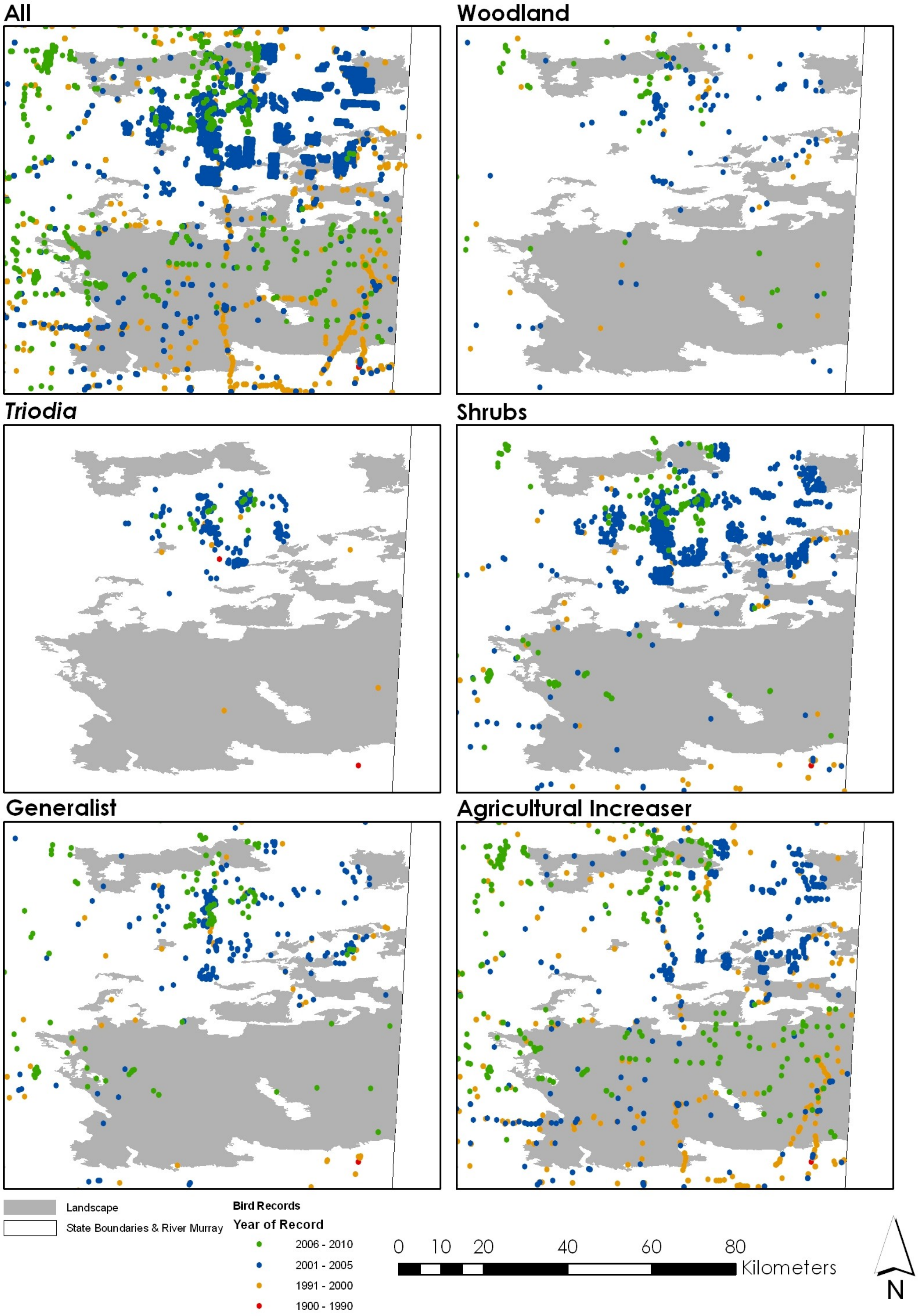


Figure 6: Spatial distribution of Murray Mallee Landscape Response Groups in the Pinnaroo landscape



LUH (Pinnaroo)

The open mallee grassland has been particularly heavily impacted for a long time by agricultural development. This landscape was cleared shortly after the early pastoral era, with the first railway opened in 1909 and most land taken up immediately (Jones 1981). The inherently open and grassy nature of the understorey on the heavier soils facilitated both grazing and clearing. The sandy areas of the landscape, while not as productive as the heavier soils, are often interspersed with the heavier soils at a property scale and were apparently most often cleared along with the flats. Occasional larger patches of remaining vegetation invariably occur where lighter soils locally dominate. The clayey flats remain very good cropping country for, predominantly, barley and wheat. There is usually some form of rotation, often including sheep grazing (McCord 1995).

More recently there has been increased use of centre pivot irrigation, primarily with potato crops, utilising ground water found at considerable depth (up to 200 metres - Mallee Water Resources Planning Committee 2000). Between the early and late 1990s, irrigated crops in the Pinnaroo landscape increased from about 250 hectares to 1150 hectares (Mallee Water Resources Planning Committee 2000).

Synthesis as precursor to goal setting

Pinnaroo is a relictual landscape, with much ecological function lost. Very few of the smaller remnants remain in good condition (observations) and are probably experiencing a long term decline through lack of recruitment and other issues caused by landscape issues affecting the remaining patches (e.g. Cale and Willoughby 2009).

Due to the relictual nature of the Pinnaroo landscape, there is little value left to maintain and the landscape could be viewed as a low priority for biodiversity conservation at a regional level. Any efforts within this landscape could focus on improving the condition of the best remaining fragments.

'Alternative' primary production could be advocated in Pinnaroo to create a more diverse matrix (e.g. Collard and Fisher 2010).

Karoonda Landscape

The Karoonda landscape includes the Bandon, Burdett, Karoonda, Kunlara, Marmon Jabuk, Sandalwood, Stirling Well and Wynarka Land Systems (McCord 1995). The Burdett Land System is included in the Karoonda landscape, based on both observation and the patterns visible in the digital elevation model (Figure 2), despite McCord (1995) suggesting it shares greater similarity with the Holder landscape by describing it with the Mantung Land System as 'Flat to undulating calcrete plains with occasional sandhills'.

The Karoonda landscape is relatively diverse compared with the rest of the Murray Mallee. It contains all the same landscape elements as surrounding landscapes, as well having areas with Parilla Sand near the surface. There are also areas in which these layers interact to some degree, such as areas with shallow sand (of Lowan origin) over Parilla Sand. This diversity is a probably a result of the higher rainfall than the northern and eastern Murray Mallee, resulting in greater fluvial erosion and deposition during inter-glacial periods, and creating eroded surfaces upon which aeolian processes could act during glacial periods.

Annual rainfall is between 300 mm and 400 mm.

EVH (Karoonda)

The diversity of geomorphology in the Karoonda landscape has created a more complex set of environmental settings in which vegetation develops (Table 4). Even more than other Murray Mallee landscapes, Karoonda highlights the continuous nature of the soil gradients and plant response in mallee (e.g. Cheal and Parkes 1989; Sparrow 1989; White et al. 2003; White 2006), rather than the discrete units implied in Table 4.

In certain areas of the landscape, various environmental settings dominate locally, so no attempt has been made here to summarise the percent of the landscape falling into each environmental setting.

Figure 7: Simple profile of Karoonda landscape

Modified from McCord (1995). Not to scale.

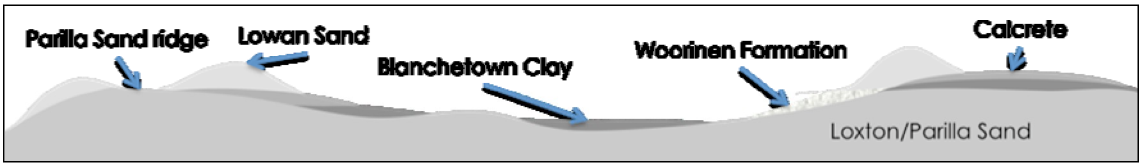


Table 4: Characteristics of Karoonda environmental settings

Modified from White et al. (2003) and Heard (2009). *E.* – *Eucalyptus. A* – *Acacia.*

Attributes	Deep sand (Lowan Sand)	Parilla Sand amongst deep sand	Shallow sand (Woorinen Formation)	Calcrete	Shallow aeolian soil over Parilla sand	Loam over Blanchetown clay (or equivalent)
Structure	Mallee shrubland	Whipstick mallee with very open shrub layer	Mallee Triodia	Open mallee woodland	Tall open mallee woodland	Grassy woodland
Overstorey	*E. incrassata, E. leptophylla, E. socialis, E. arenacea* (in the south)	*E. dumosa, E. calycogona, E. socialis*	*E. dumosa, E. socialis, E. leptophylla*	*E. oleosa, E. dumosa, E. gracilis, E. socialis, E. yalatensis*	*E. oleosa, E. dumosa, E. socialis, Callitris gracilis*	*E. porosa, Callitris gracilis*
Mid & understorey	*Callitris verrucosa* becomes increasingly dominant if unburnt			Clumps of *Callitris canescens*, *Melaleuca lanceolata* and occasional *Melaleuca acuminata* occur as an upper layer over a sparse but diverse cover of mid to low shrubs		An open cover of native grasses with the occasional low shrubs, *Lomandra effusa, Gahnia lanigera* and daisies make up the understorey.
Ground layer	Annual, short lived herbs	Scattered grasses, sedges and herbs. Clematis microphylla.	Forbs are seasonally common in the inter-tussock spaces	Range of grasses and forbs	Diverse	Grasses and sedges with inter-tussock herb layer
Notes	Fire becomes increasingly important as the deep sand patch increases in size. The density and size of shrub patches decreases to the northeast along the climate gradient	The landscape context of these patches increases the importance of fire in determining the whipstick structure of these patches	Mallee *Triodia* only becomes a significant landscape component towards the north of this landscape	Shrub layer floristic and structural diversity decreases to the northeast along climate gradients	Poorly understood as so few good patches remain	Patches of this environmental setting are found throughout the Karoonda landscape in locally low settings

LRG (Karoonda)

There are 50 sites at which repeat visit bird surveys have occurred in the Karoonda landscape (Figure 8). All the LRG, except the *Triodia* LRG, were recorded in the Karoonda landscape, even with only a few sites in some of the environmental settings. The Agricultural Increaser LRG is now ubiquitous on the shallow sand and deep sand (north), while conversely the Shrubs LRG has been lost from the north deep sand and all other LRG have been lost in the shallow sand environmental setting. In contrast, the Shrubs LRG has its highest mean proportion of presence of all landscapes within the southern deep sand environmental setting of the Karoonda landscape, although it is also commonly present in the two Parilla Sand influenced environmental settings, except swales amongst deep sand, possibly reflecting the effect of the climate gradient on the shrub layer of all vegetation types – decreasing diversity, shrub patch size and overall cover moving northeast along climate gradients.

The mean proportion of the Woodland LRG present within appropriate environmental settings is also relatively high within the Karoonda landscape.

There are currently no sites at which repeat visit bird surveys have occurred in the clay depression environmental setting.

For all LRGs remaining in the Karoonda landscape, the distributional information, summarised in Figure 9, suggests that they are currently clumped in certain areas of the landscape, rather than distributed widely.

Figure 8: Mean proportion of LRG species present at sites within each environmental setting in the Karoonda landscape

Error bars are standard error, with sample sizes as follows; Shallow (Woorinen) Sand: 3 sites, Deep (Lowan) Sand - south: 9 sites, Deep (Lowan) Sand - north: 3 sites, Shallow Lowan Sand over Parilla Sand: 3 sites, Parilla Sand swales: 4 sites, Woorinen Formation calcrete: 16 sites, Shallow deposits on Parilla Sand: 12 sites

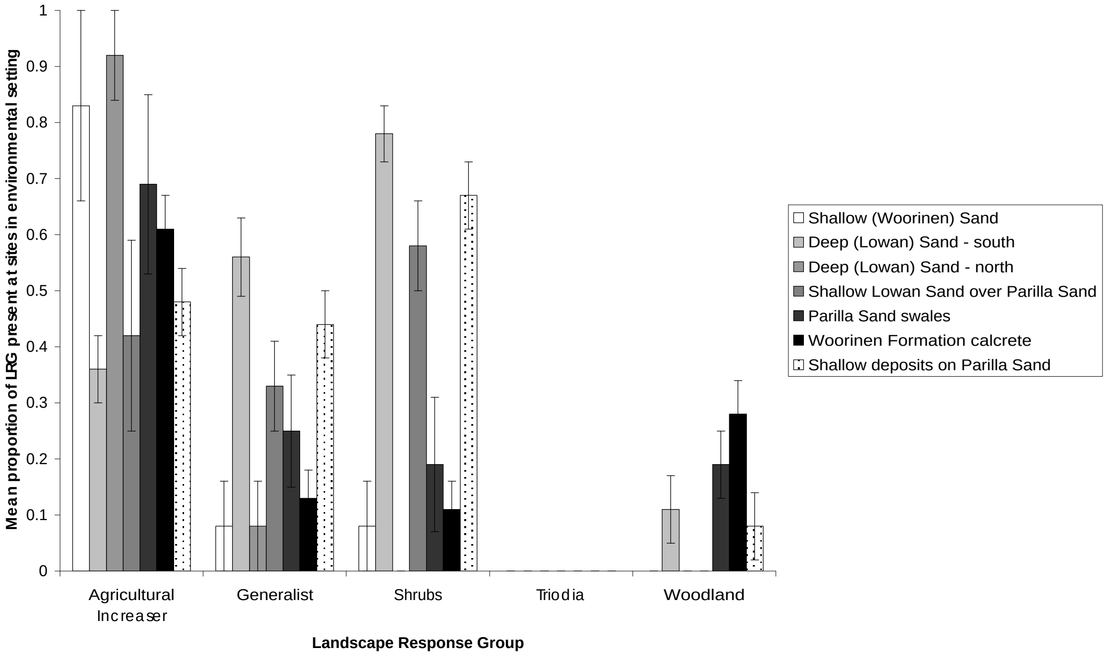
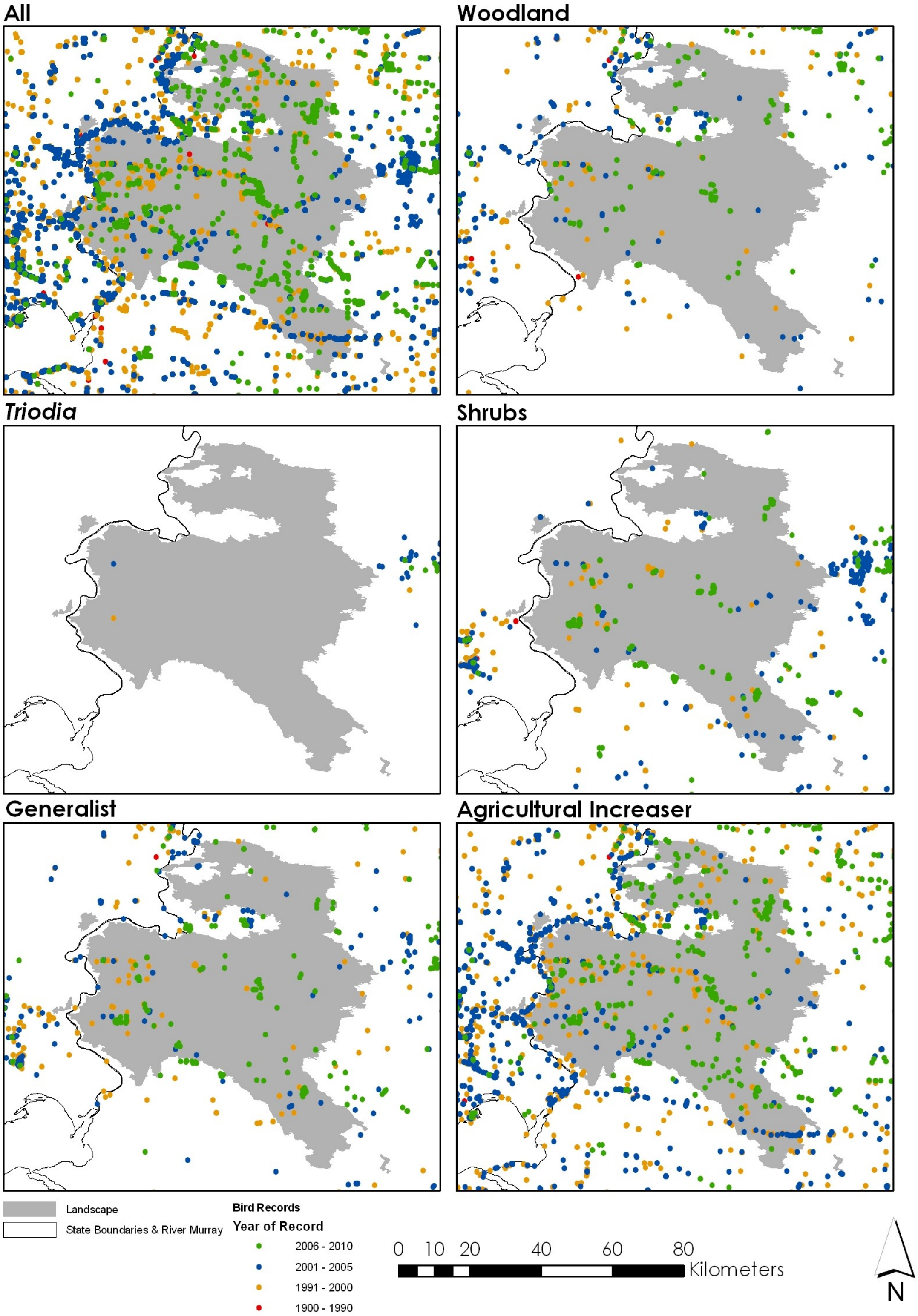


Figure 9: Spatial distribution of Murray Mallee Landscape Response Groups in the Karoonda landscape



LUH (Karoonda)

As with the rest of the mallee, the railways allowed agricultural intensification, after an early pastoral era that was abandoned. The railways were opened in the early 1910s, with most land taken up soon after, particularly towards the south of the landscape, closer to the Karoonda railway. While some early abandonment occurred, by the late 1920s those sections were again taken up (Jones 1986). A large fire occurred in 1911 at the same time most settlers were starting the clearing process, making it harder to clear as it left a lot of scorched, dead mallee standing over much of the country (Jones 1986). Towards the north of the landscape, the Karoonda – Waikerie railway was completed in 1914, allowing this country to be settled. The country around Perponda and Kalyan proved to be reasonable agricultural land, with the red sand (Woorinen Formation) being relatively fertile (Jones 1986, p. 253). The interaction of distance to the railway and stoniness (calcrete development) of the soil guided clearance levels. In areas where clearance was not possible, grazing sheep was the dominant landuse by the 1920s. Clearance enable improved pasture and stocking rates, with clearance and agricultural intensification continuing until the 1960s (Jones 1986).

Despite being relatively close to the river, the southern parts of the hundred of Bowhill were slow to develop due to travelling times to either the river or the railway and due to the stony nature of the ground which could not be used for cropping, but made good grazing country once cleared. These areas were only more fully developed for agriculture after improved roads and machinery, for both clearing and transport, enabled this after war time shortages had come to an end in the late 1940s. Clearing and development was still going on almost to 1960 (Jones 1986).

Synthesis as precursor to goal setting

While retaining all LRG, except *Triodia*, the Karoonda landscape is very highly cleared (relictual). Areas where landscape function is best, as indicated by the presence of all LRG appear concentrated in areas where vegetation cover is locally higher within the landscape. In order to maintain and restore landscape function, restoration work should focus on these areas and their immediate surroundings ('buffer core population areas'), with the emphasis being on restoring the sandy environmental settings in the north, and the environmental settings that provide open vegetation types in the south.

Sherlock Landscape

The Sherlock landscape includes the Buccleuch and Sherlock Land Systems (McCord 1995). These areas are described as primarily calcrete plains, with occasional sandhills (very flat and no dunes in the case of Buccleuch). Annual rainfall is around 400mm.

EVH (Sherlock)

Around 10% of the landscape is sandy, the remainder being the stony flats and rises of either the calcrete or coastal lagoon limestone.

Figure 10: Simple profile of Sherlock landscape

Modified from McCord (1995). Not to scale.

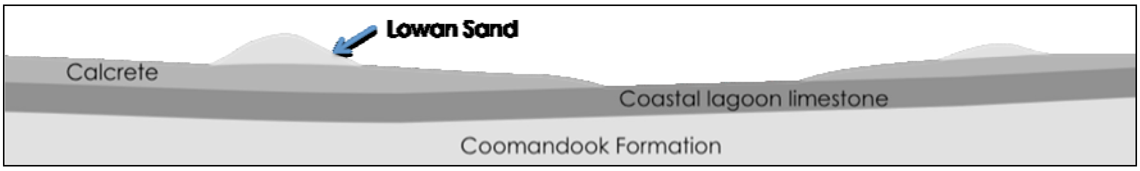


Table 5: Characteristics of Loxton environmental settings

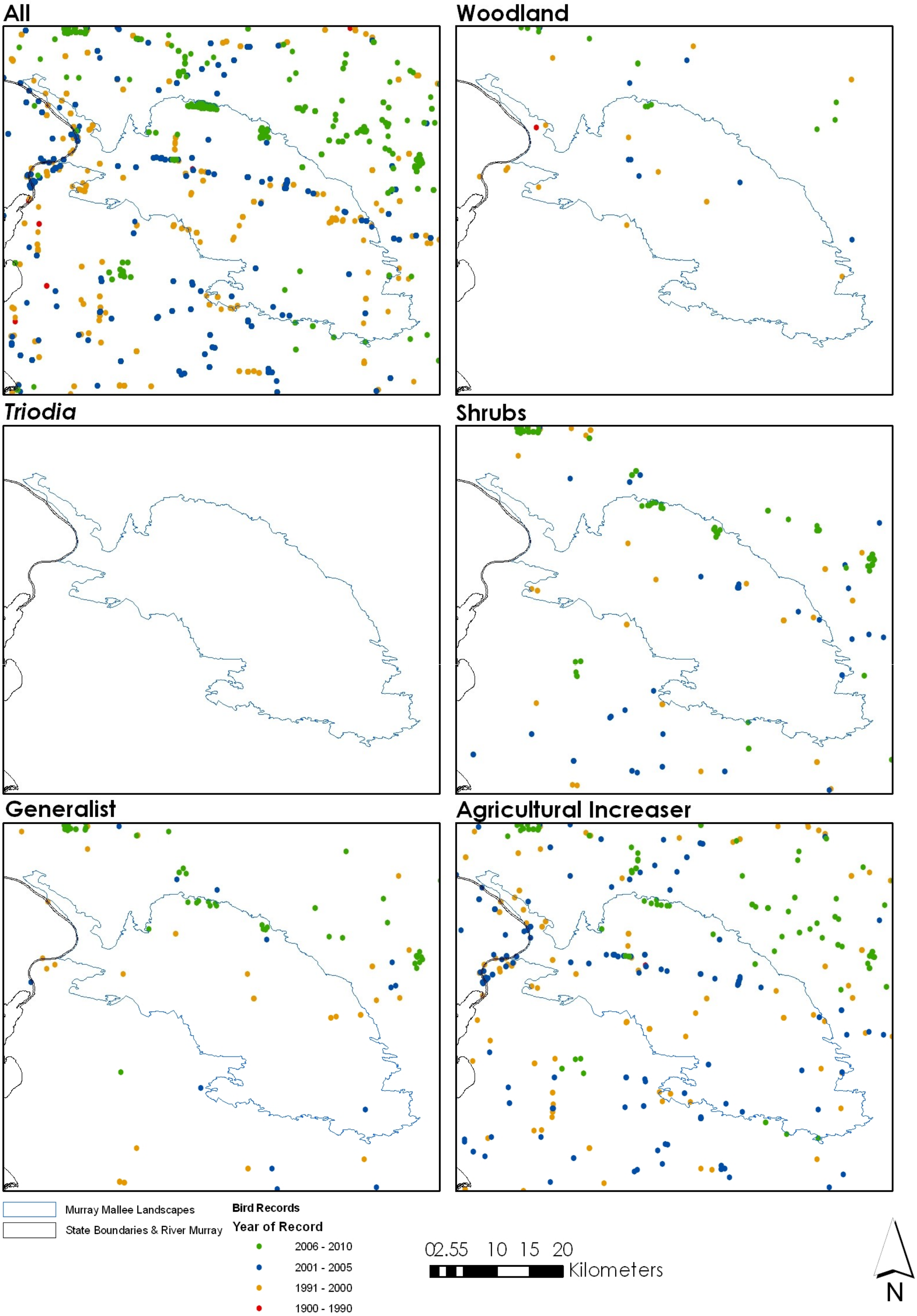
Modified from Heard (2009). *E. – Eucalyptus. A – Acacia.*

Attributes	Deep (Lowan) Sand	Calcrete
Structure	Mallee shrubland	Mallee woodland
Overstorey	*E. dumosa, E. leptophylla, E. socialis, E. incrassata*	
Mid & understorey		
Ground layer		
Notes		

LRG (Sherlock)

There are been no sites with repeat visit surveys for birds in the Sherlock landscape. There has also been little recent effort, although a small amount of fieldwork in winter 2010 started to improve the information available for birds within the landscape. The distribution of each LRG in the Sherlock landscape is given in Figure 11. The lack of recent information makes it hard to generate hypotheses about the current landscape, but the Shrubs LRG does appear relatively widespread (Joel Allen, pers. comm., June 2010).

Figure 11: Spatial distribution of Murray Mallee Landscape Response Groups in the Sherlock landscape



LUH (Sherlock)

A landuse history for the Sherlock landscape has not been consolidated.

Synthesis as precursor to goal setting

The Sherlock landscape is not currently understood well enough to prioritise restoration actions needed to maintain landscape function as indicated by LRGs. Preliminary consolidation of available information suggests that the Woodland LRG is most likely to be indicating loss of function. Thus, targeting those environmental settings in which the open woodland vegetation type develops could be a priority.

Testing the preliminary consolidation of data will be a priority over the 2010-2011 year.

Holder Landscape

The landscape described here under the name Holder includes the Holder, Mantung and Wanbi Land Systems (Potter et al. 1973; McCord 1995). These Land Systems include various outliers from the main landscape which is centred around the township of Maggea and extends east to the Victorian border. The outliers are part of the component Land Systems in the underlying mapping. The main outliers are:

- 18,500 hectares near Purnong to the southwest of the main Holder landscape
- 13,000 hectares near Yamba to the northeast of the main Holder landscape
- 5,000 hectares east of Swan Reach to the west of the main Holder landscape
- 2,300 hectares near Morgan to the northwest of the main Holder landscape.

While sharing the same characteristics as the main Holder landscape, the conservation values of these outliers are probably better considered in the context of their surrounding rather than directly as part of Holder. For example, the Purnong outliers could be considered parts of the Karoonda landscape that have a higher calcrete component than is generally found in that landscape. The main Holder landscape also surrounds an area around Bakara Well that is more similar to the Blanchetown landscape to the west of Holder. These changes have not been made within this version of the LAF applied to the Murray Mallee.

Annual rainfall is between 300 mm and 250 mm.

EVH (Holder)

The Holder landscape consists of a flat to undulating calcrete plain with occasional sandhills. The sandy areas occupy 10 to 20% of the landscapes and are scattered throughout. Woorinen Formation dunes are characterised by east-west longitudinal dunes, a few hundred metres to a kilometre or so in length, 2-3 but up to 10 metres high and generally slightly steeper south faces (Potter et al. 1973). At times areas of Lowan Sand are incorporated into the Holder landscape.

Characteristically, the calcrete areas develop an open mallee woodland vegetation type, while the sandy areas develop either a mallee shrubland or mallee over *Triodia* depending on the depth of the sand and the history of the patch. In long unburnt patches *Callitris* can become dominant, creating a *Callitris* woodland.

Due to the larger proportion of the landscape being characteristically open, fire would have been less of an influence on the Holder landscape than the neighbouring Lowan Mallee landscape of Billiatt. This may have led to floristically similar, but structurally different, Lowan Sand vegetation types in the two landscape types (White 2006), and facilitated the dominance of *Callitris* in sandy settings.

Figure 12: Simple profile of Holder landscape

Modified from Potter et al. (1973) and McCord (1995). Not to scale

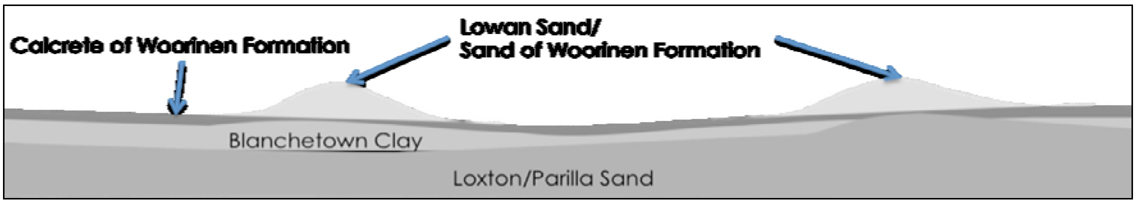


Table 6: Characteristics of Holder environmental settings

Modified from White et al. (2003) and Heard (2009). *E. – Eucalyptus. A – Acacia.*

Attributes	Deep (Lowan) Sand	Shallow (Woorinen) Sand	Woorinen Formation Calcrete
Structure	Mallee shrubland	Mallee Triodia	Mallee woodland
Overstorey	*E. incrassata, E. leptophylla, E. socialis*	*E. dumosa, E. socialis*	*E. oleosa, E. dumosa, E. gracilis, E. socialis*
Mid & understorey	*Callitris verrucosa* becomes increasingly dominant if unburnt. Patchily dense shrub layer	*Triodia* is dominant in the understorey with occasional shrubs	Very open, very low shrub layer
Ground layer	Annual, short lived herbs	Forbs are seasonally common in the inter-tussock spaces	Range of grasses and forbs

LRG (Holder)

There are nearly 100 sites in Holder at which repeat visit bird surveys have occurred. From these, it is clear that all the LRG, except *Triodia*, are present within the landscape. The mean proportion of the Shrubs LRG present at sites with suitable habitat for this group in this landscape (deep sand) is similar to that of the Woodland LRG (Figure 13), however unlike the Woodland LRG, the Shrubs LRG are now constrained to just one or two (depending on species) areas of the landscape – a northern core around Stockyard Plains Disposal Basin and a southern core around Bakara Conservation Park and surrounding native vegetation on private land Figure 14. The Woodland LRG remains widespread in remaining native vegetation within the region, while the Generalist LRG shows an intermediate current distribution. A greater proportion of the Agricultural Increaser LRG is present on average at sites within Holder than the other LRG, however compared to other Murray Mallee landscapes it is considerably less ubiquitous (e.g. compare with Pinnaroo Figure 5 or Loxton Figure 16).

Figure 13: Mean proportion of LRG species present at sites within each environmental setting in the Holder landscape

Error bars are standard error, with sample sizes as follows; Shallow (Woorinen) Sand: 26 sites, Deep (Lowan) Sand - north: 18 sites, Woorinen Formation calcrete: 53 sites

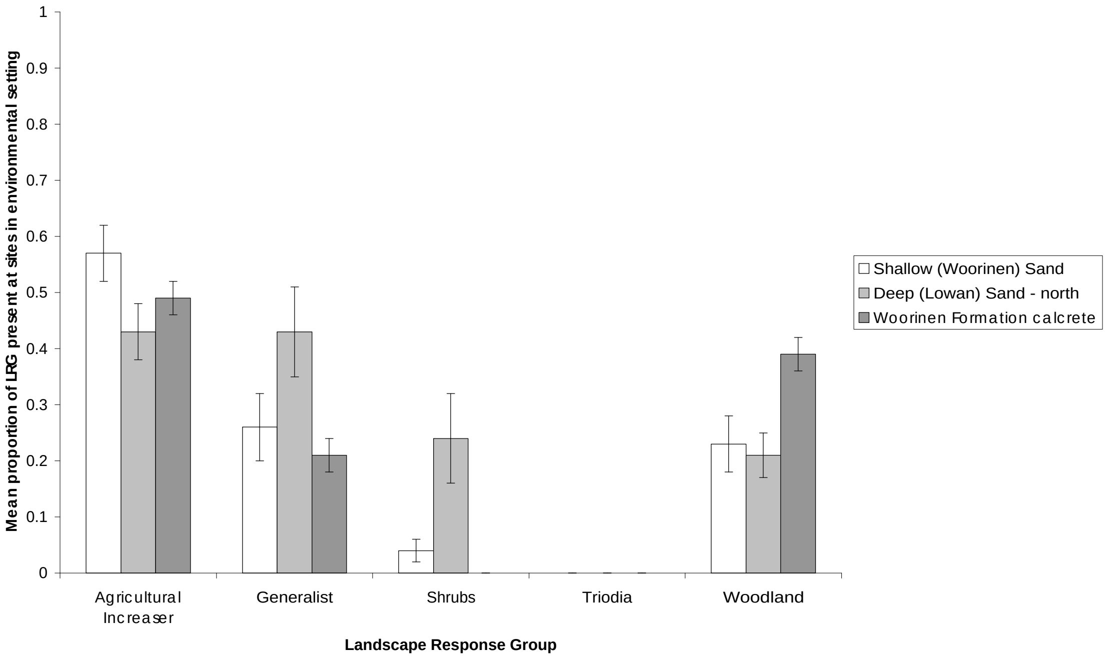
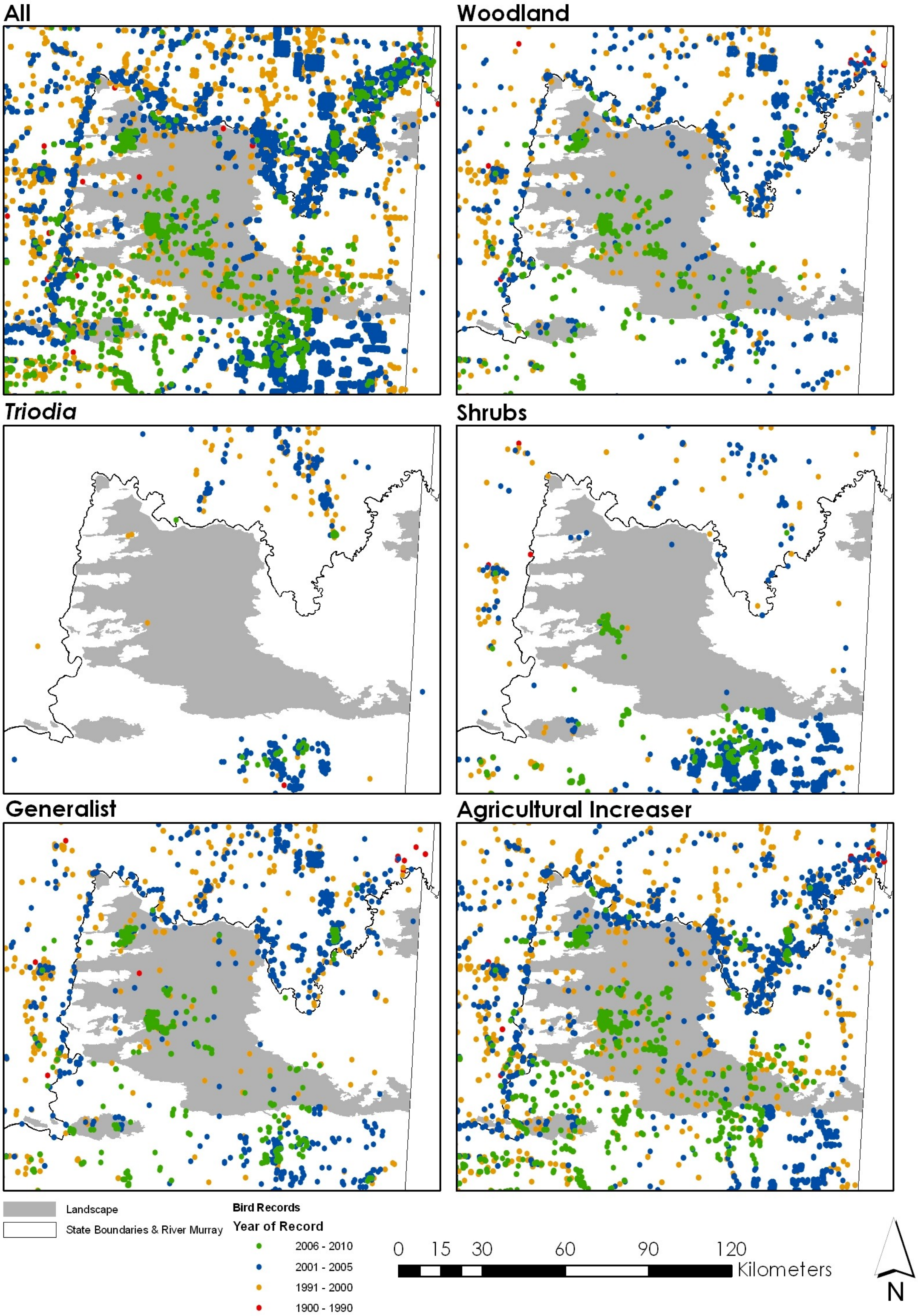


Figure 14: Spatial distribution of Murray Mallee Landscape Response Groups in the Holder landscape



LUH (Holder)

While the general Murray Mallee landuse history applies to the Holder landscape, there are a few differences worthy of note. Due to the lower rainfall and the amount of calcrete in the soil profile of the flats, farmers favoured the sandier areas of the landscape for clearance (Barratt et al. 1991), which were easier to work and have better water relations at this part of the climate gradient. This led to preferential clearance of the dune systems, but also left good areas of native vegetation on the calcrete. These areas didn't escape development altogether though, as they were cut over for firewood and charcoal. Around Mantung, large amounts of firewood were cut for sale in Adelaide, with up to 50 woodcutters active at times. Major firewood cutting occurred in the late 1910s and most of the 1920s and again in the 1940s. At these times the Mantung railway station was busy throughout the year and at the busiest times of year a train a day was leaving Mantung for Adelaide with firewood (Jones 1986).

Synthesis as precursor to goal setting

Holder is a fragmented landscape, with some landscape function intact, as indicated by the LRGs. However, preferential clearance of vegetation on sandy soils has depleted vegetation on the most productive environmental setting within this landscape. The Shrubby LRG, most closely associated with deep sand, has contracted in distribution to the areas that still support native vegetation, suggesting loss of function from this environmental setting throughout much of the landscape. Restoration to maintain landscape function associated with the deep sand environmental setting should focus on restoring appropriate patches, initially focussing on the area surrounding Bakara Conservation Park (buffer core population areas).

Landscape Goals

As the Holder landscape has an active Landscape Recovery Group, who have considered the information available and determined appropriate goals for the landscape, those landscape goals are provided below:

- Maintain the Woodland vegetation type and its corresponding Woodland LRG.
- Restore the deep sand environmental setting to improve its' function within the landscape. One expected outcome of this work is that populations of the Shrub and Generalist LRGs will become more viable in the landscape, with viability of those LRG guiding current restoration efforts.

Loxton Landscape

The Loxton landscape is made up of the Loxton and Noora Land Systems (Potter et al. 1973). Loxton is similar to Holder in its geomorphology and soils, although it has a deeper sandy loam layer above the calcrete of the Woorinen Formation (deeper Loveday Soil). It can be 75 cm to the rubbly calcrete in the Loxton landscape compared to less than 30 cm in the Holder landscape (Potter et al. 1973). Due to the deeper soil, which is easier to work, the area has been more heavily cleared for agriculture than the Holder landscape. The Noora Land System is lower in relation to the water table, intersecting it in places. The water table in this area is saline, creating low lying saline lakes and swamps, interspersed with landforms similar to the Loxton Land System.

EVH (Loxton)

The Loxton landscape is an undulating calcrete plain with occasional sandhills. The sandy areas occupy 25% of the landscape and are scattered throughout, generally as Woorinen Formation dunes, characterised by east-west longitudinal dunes, a few hundred metres to a kilometre or so in length, 2-3 but up to 10 metres high and generally slightly steeper south faces (Potter et al. 1973). At times areas of Lowan Sand are incorporated into the Holder landscape.

Characteristically, the calcrete areas develop an open mallee woodland vegetation type, while the sandy areas develop either a mallee shrubland or mallee over *Triodia* depending on the depth of the sand and the history of the patch. In long unburnt patches *Callitris* can become dominant, creating a *Callitris* woodland.

Due to the larger proportion of the landscape being characteristically open, fire would have been less of an influence on the Holder landscape than the neighbouring Lowan Mallee landscape of Billiatt. This may have led to floristically similar, but structurally different, Lowan Sand vegetation types in the two landscape types (White 2006), and facilitated the dominance of *Callitris* in sandy settings.

Figure 15: Simple profile of Loxton landscape

Modified from Potter et al. (1973). Not to scale.

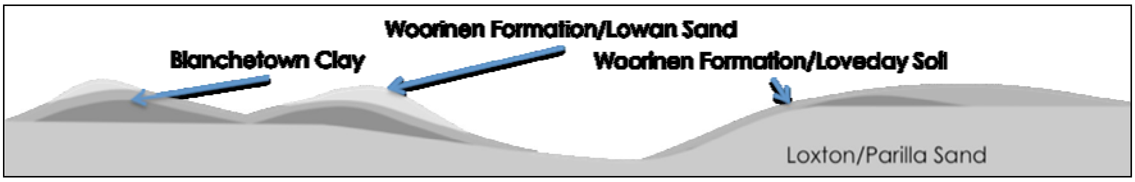


Table 7: Characteristics of Loxton environmental settings

Modified from White et al. (2003) and Heard (2009). *E. – Eucalyptus. A – Acacia.*

Attributes	Deep (Lowan) Sand	Shallow (Woorinen) Sand	Woorinen Formation Calcrete	Saline Clay Pans
Structure	Mallee shrubland	Mallee Triodia	Mallee woodland	Low open shrubland or herbland
Overstorey	*E. incrassata, E. leptophylla, E. socialis*	*E. dumosa, E. socialis, E. cyanophylla*	*E. oleosa, E. dumosa, E. gracilis, E. socialis*	Low open shrub layer of succulent chenopods. Commonly *Halosarcia halocnemoides* and *Halosarcia pergranulata*
Mid & understorey	*Callitris verrucosa*	*Triodia* is dominant in the understorey with sparsely scattered tall to low shrubs	Very low, very open shrub layer	
Ground layer	Annual, short lived herbs	Daisies and native grasses, some seasonally common, in the inter-tussock spaces	Range of grasses and forbs	
Notes	*Callitris* becomes increasingly dominant if unburnt			There is a gradual change in floristics and structure along a salinity gradient from the saline clay pans to the areas of the landscape not influenced by salinity. Vegetation clearance in the surrounding landscape has led to an increase in water table level, creating vegetation changes at all levels along the salinity gradient.

LRG (Loxton)

The eighteen sites in the Loxton landscape with repeated, standardised bird surveys (Figure 16) show that the *Triodia* and Shrubs LRG have been lost from the area and the Generalist LRG has seriously declined (one record each, at different sites, of Variegated Fairy-wren and Crested Bellbird). Perhaps surprisingly, the mean proportion of the Woodland LRG recorded is similar to other landscapes, including within the shallow sand environmental setting which would normally not be expected as Woodland LRG habitat due to the characteristic *Triodia* layer. The Agricultural Increaser LRG is now ubiquitous in native vegetation of the landscape. Distributional information is given in Figure 17.

No sites with repeat visit bird surveys have occurred in the Noora Land System and its associated saline clay pans environmental setting.

Figure 16: Mean proportion of LRG species present at sites within each environmental setting in the Loxton landscape

Error bars are standard error, with sample sizes as follows; Shallow (Woorinen) Sand: 4 sites, Woorinen Formation calcrete: 14 sites

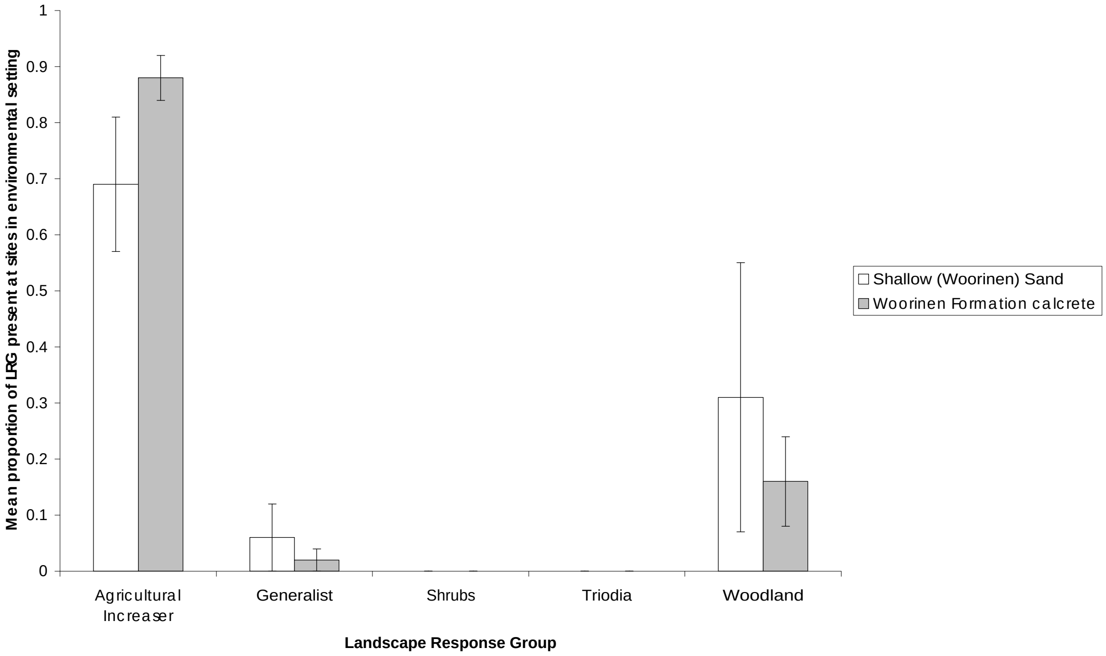
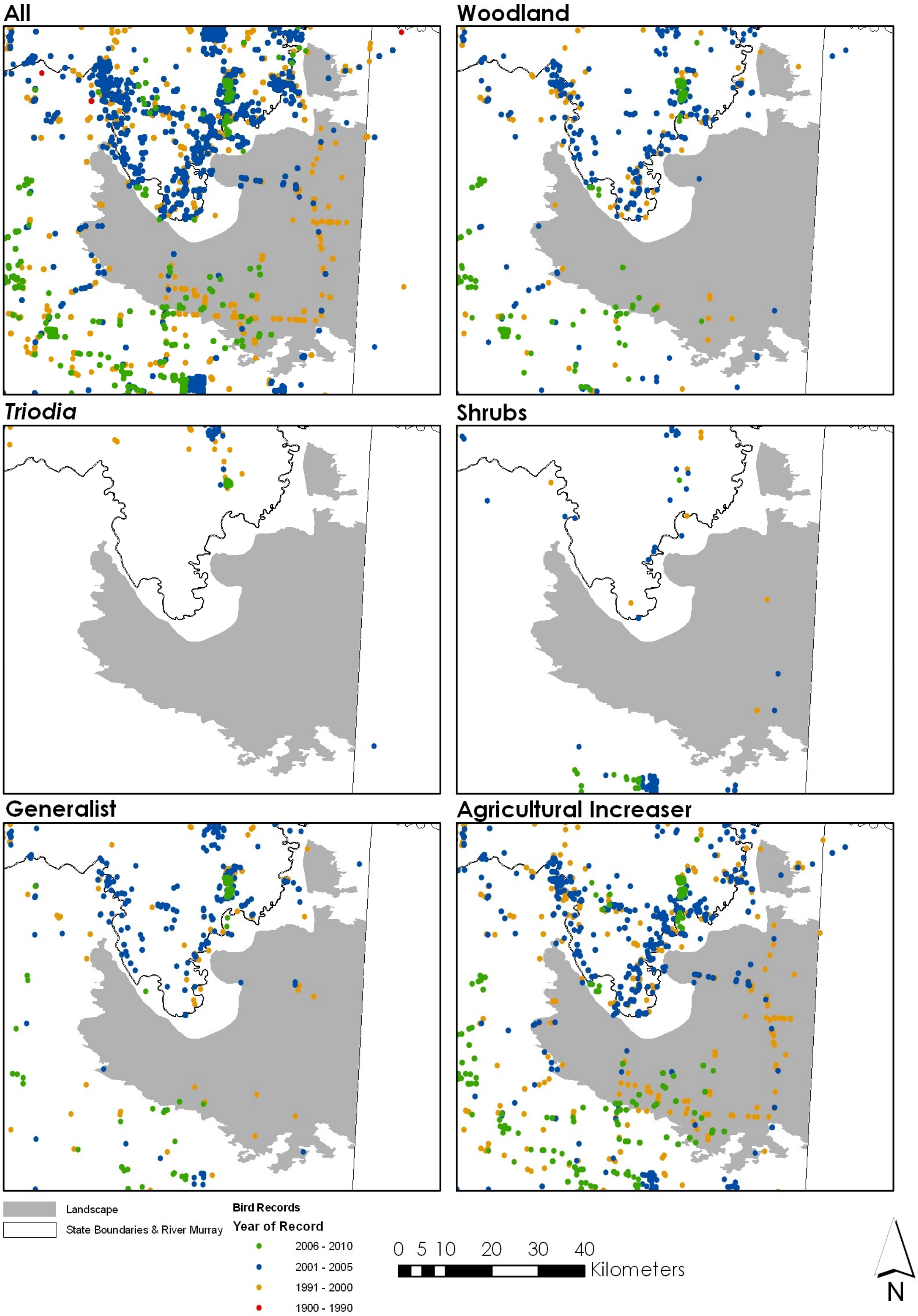


Figure 17: Spatial distribution of Murray Mallee Landscape Response Groups in the Loxton landscape



LUH (Loxton)

Areas close to the river in the Loxton landscape have been cropped since the late 1800s (Jones 1986), although serious development for agriculture only started after the railway was extended from Alawoona to Loxton (in 1914) (Kloeden et al. 1998). Despite similarity in the underlying geomorphology and ecology with the neighbouring Big Desert area of Victoria, the Loxton landscape has a markedly different landuse history, being cleared, cropped and grazed in South Australia, while just grazed in Victoria. Today, the Victorian side of the border is no longer grazed by stock and is mostly conservation land. These different landuse histories have created landscapes with very different management priorities to retain remaining function.

Synthesis as precursor to goal setting

The Loxton landscape has lost much of its function with respect to the bird LRGs. Surprisingly, the remaining function appears stable, as indicated by the Woodland LRG. However, it is likely that there is slow, ongoing, further decline of function due lack of recruitment of the characteristic mallee overstorey.

Very few remnants in good condition remain, with significant structural changes of remaining native vegetation occurring (e.g. the significant presence of the Woodland LRG within environmental setting usually unsuitable. The loss of much *Triodia* cover allowing this habitat to be used by the Woodland LRG).

Due to the loss of landscape function as indicated by the LRGs, biodiversity conservation priorities are low priority relative to other landscapes of the region.

While not indicated by data on bird LRGs, addressing issues of changed water cycling are necessary to prevent ongoing change to the salinity influenced vegetation types in the Noora Land System.

'Alternative' primary production could be advocated in the Loxton landscape to create a more diverse matrix (e.g. Collard and Fisher 2010).

Remaining Landscapes

The remaining Landscapes are awaiting the collection of new data and analyses of data. These Landscapes will be completed as follows:

- 2010-2011 – Blanchetown, Mount Mary, Sedan, Brownlow, Punthari Landscapes
- 2012-2013 – remaining Murray Mallee IBRA sub-region landscapes, adjacent to, and often described as, the Eastern Mount Lofty Ranges.

For the Lowan landscapes of Billiatt and Ngarkat, LAF will be completed on an *ad hoc* basis over the next few years. Generally, in the Lowan landscapes, management emphasis should be on threatened species rather than landscape management as the high remaining native vegetation cover has enabled much landscape function to remain intact.

Next Step

The next step in the planning cycle (Figure 1) is to take the information generated here to stakeholders to define restoration goals on the basis of the landscape assessments. For the Pinnaroo, Karoonda and Sherlock landscapes, the existing Woorinen Landscape Recovery Group is an appropriate group to at least start that process. The Woorinen Landscape Recovery Group have already been active in the northern Murray Mallee for several years, implementing the goals set on the basis of the LAF for the Holder landscape. No work has yet been prioritised within the Loxton landscape by that group.

A key gap in the current landscape planning is integration of threatened species information specific to each landscape. While this is not the aim of the LAF, and LAF is not designed to determine threatened species requirements, the Landscape Recovery Groups that implement work based on LAF are a suitable group to assist building threatened species requirements into the landscape priorities.

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Appendices

Appendix 1: Land System Information

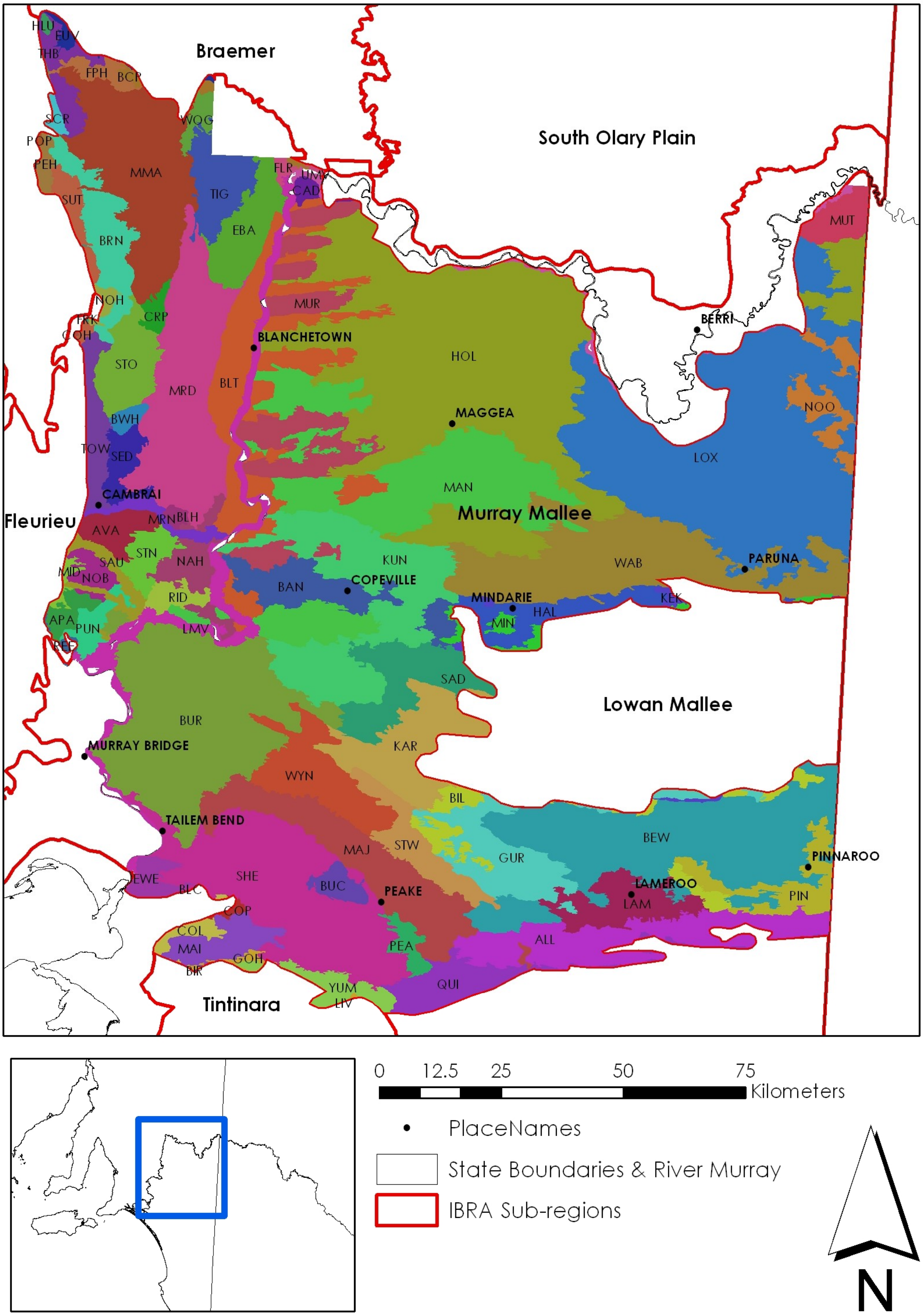
Land Systems (Potter et al. 1973; McCord 1995) are shown in colours and labelled with land system code. Spatial layer of Land Systems accessed from BDBSA – EGIS (access date 30/06/2010).

Land System	Area (ha)
ALE	400
ALL	50670
APA	5440
ARC	3300
AVA	9990
BAN	25890
BCP	2190
BEW	120610
BIL	134020
BLH	1730
BLT	66480
BRK	22690
BRN	24020
BUC	6000
BUR	118220
BWH	2880
CAD	2370
CLY	750
COL	4060
COP	960
CRD	3620
CRP	3610
EBA	21370
EMU	650
EUV	1840
EWE	6240
FIN	420

Land System	Area (ha)
FIS	17910
FLR	1760
FPH	5120
GIH	7900
GOH	9940
GUR	61590
HAL	33340
HAR	5190
HLU	840
HOL	238820
JER	5670
KAR	47360
KEK	60760
KIN	3950
KUN	74450
LAM	21740
LAW	9520
LHC	9370
LIV	2940
LMV	45430
LON	1270
LOW	23660
LOX	190240
MAI	13670
MAJ	53950
MAL	2680
MAN	104960

Land System	Area (ha)
MCA	27710
MID	1740
MIL	11160
MIN	57780
MMA	68380
MNS	2110
MOS	3630
MRD	74350
MRE	43080
MRN	6180
MUR	46880
MUT	10620
NAH	13810
NAR	390
NGA	136210
NOB	6050
NOH	1980
NOO	13600
PAL	5070
PEA	5610
PEH	3190
PIN	18420
PND	3990
POP	250
PUN	7590
QUI	155910
REE	910

Land System	Area (ha)
RID	5510
SAC	1940
SAD	31930
SAU	7650
SCR	1670
SED	9010
SEN	20560
SHA	61140
SHD	18160
SHE	91380
STN	9330
STO	20140
STW	18740
SUT	7800
THB	10340
TIG	18730
TOW	13100
UMV	3860
URB	1780
WAB	93420
WHH	10220
WOG	4300
WOL	700
WYN	30880
YUM	9630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Murray Mallee
Lowan Mallee
Fleurieu
Tintinara
BLANCHETOWN
MAGGEA
BERRI
CAMBRAI
COPEVILLE
MINDARIE
PARUNA
MURRAY BRIDGE
TAILEM BEND
PEAKE
LAMEROO
PINNAROO
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State Boundaries & River Murray
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Appendix 2: Proportion of all sites within a landscape at which each species was recorded during repeat visit bird surveys

Only data generated as part of this project are included. The total number of sites with three repeat visits in each landscape is also given. Blank cells indicate no records of that species in that landscape.

Common Name	Species	Landscapes				
		Billiatt	Holder	Karoonda	Loxton	Pinnaroo
	Sites in landscape with three repeat visits	61	99	56	19	11
Australasian Pipit	*Anthus novaeseelandiae*		0.03	0.05		0.18
Australian Magpie	*Cracticus tibicen*	0.38	0.88	0.91	0.84	1
Australian Owlet-nightjar	*Aegotheles cristatus*		0.05	0.04	0.16	0.18
Australian Raven	*Corvus coronoides*	0.23	0.56	0.09	0.32	0.18
Australian Ringneck	*Barnardius zonarius*	0.21	0.66	0.64	0.58	0.09
Australian Shelduck	*Tadorna tadornoides*		0.01			
Banded Lapwing	*Vanellus tricolor*		0.01	0.02		
Black Falcon	*Falco subniger*			0.02		
Black Kite	*Milvus migrans*			0.02		
Black-eared Cuckoo	*Chalcites osculans*	0.02	0.01	0.02		
Black-faced Cuckoo-shrike	*Coracina novaehollandiae*	0.15	0.22	0.16	0.11	0.27
Black-faced Woodswallow	*Artamus cinereus*		0.01		0.05	0.09
Black-shouldered Kite	*Elanus axillaris*			0.02		
Blue Bonnet	*Northiella haematogaster*	0.02	0.09	0.23	0.63	0.45
Brown Falcon	*Falco berigora*	0.02	0.03	0.04	0.11	0.18
Brown Goshawk	*Accipiter fasciatus*	0.03	0.02	0.02	0.05	
Brown Songlark	*Cincloramphus cruralis*	0.03	0.05	0.46		0.91
Brown Treecreeper	*Climacteris picumnus*		0.26	0.02	0.32	
Brown-headed Honeyeater	*Melithreptus brevirostris*	0.43	0.39	0.7	0.26	0.55
Budgerigar	*Melopsittacus undulatus*	0.02				0.09
Buff-rumped Thornbill	*Acanthiza reguloides*		0.01			
Bush Stone-curlew	*Burhinus grallarius*		0.01			
Chestnut Quail-thrush	*Cinclosoma castanotum*	0.31	0.32	0.25		0.09
Chestnut-crowned Babbler	*Pomatostomus ruficeps*		0.01	0.04		
Chestnut-rumped Thornbill	*Acanthiza uropygialis*	0.34	0.42	0.46	0.21	0.27
Cockatiel	*Nymphicus hollandicus*		0.02	0.18		0.55
Collared Sparrowhawk	*Accipiter cirrhocephalus*			0.02		
Common Bronzewing	*Phaps chalcoptera*	0.39	0.4	0.75	0.11	0.64
Common Starling	*Sturnus vulgaris*	0.02	0.03	0.2	0.26	0.45
Crested Bellbird	*Oreoica gutturalis*	0.28	0.37	0.2	0.05	0.09
Crested Pigeon	*Ocyphaps lophotes*	0.03	0.27	0.45	0.95	0.64
Crimson Chat	*Epthianura tricolor*			0.02		
Crimson Rosella	*Platycercus elegans*		0.01			
Dusky Woodswallow	*Artamus cyanopterus*	0.05	0.1	0.02	0.11	
Elegant Parrot	*Neophema elegans*			0.09		0.09
Emu	*Dromaius novaehollandiae*	0.2	0.15			
Eurasian Skylark	*Alauda arvensis*		0.01	0.23		0.18
Fairy Martin	*Petrochelidon ariel*		0.01			
Galah	*Eolophus roseicapillus*	0.46	0.76	0.79	0.79	0.82

Common Name	Species	Landscapes				
		Billiatt	Holder	Karoonda	Loxton	Pinnaroo
Gilbert's Whistler	*Pachycephala inornata*	0.03	0.04			0.09
Golden Whistler	*Pachycephala pectoralis*	0.43	0.04	0.52		0.55
Grey Butcherbird	*Cracticus torquatus*	0.61	0.6	0.64	0.11	0.18
Grey Currawong	*Strepera versicolor*	0.41	0.41	0.68		0.27
Grey Fantail	*Rhipidura albiscapa*	0.02	0.02	0.02		0.18
Grey Shrike-thrush	*Colluricincla harmonica*	0.77	0.87	0.88	0.21	0.73
Grey-fronted Honeyeater	*Lichenostomus plumulus*		0.05		0.21	
Hooded Robin	*Melanodryas cucullata*	0.07	0.18	0.18	0.21	0.27
Horsfield's Bronze-cuckoo	*Chalcites basalis*	0.05	0.05	0.36		0.55
House Sparrow	*Passer domesticus*		0.01		0.11	0.18
Inland Thornbill	*Acanthiza apicalis*	0.72	0.05	0.2		0.27
Jacky Winter	*Microeca fascinans*	0.2	0.65	0.38	0.11	
Little Corella	*Cacatua sanguinea*		0.01			
Little Crow	*Corvus bennetti*	0.05	0.1		0.05	
Little Eagle	*Hieraaetus morphnoides*					0.09
Little Raven	*Corvus mellori*	0.07	0.24	0.91		1
Magpie-lark	*Grallina cyanoleuca*		0.01	0.11	0.05	0.27
Major Mitchell's Cockatoo	*Lophocroa leadbeateri*		0.06			
Malleefowl	*Leipoa ocellata*	0.2	0.11	0.29		
Masked Woodswallow	*Artamus personatus*	0.31	0.45	0.41	0.42	0.64
Mulga Parrot	*Psephotus varius*	0.11	0.36	0.36	0.26	0.09
Nankeen Kestrel	*Falco cenchroides*		0.06	0.02	0.11	
New Holland Honeyeater	*Phylidonyris novaehollandiae*					0.09
Pallid Cuckoo	*Cacomantis pallidus*			0.05		0.09
Peaceful Dove	*Geopelia placida*	0.13	0.03	0.2	0.16	0.09
Pied Butcherbird	*Cracticus nigrogularis*	0.02				0.09
Purple-crowned Lorikeet	*Glossopsitta porphyrocephala*	0.02	0.25			
Purple-gaped Honeyeater	*Lichenostomus cratitius*	0.31	0.06	0.39		0.27
Rainbow Bee-eater	*Merops ornatus*	0.13	0.35	0.29	0.47	0.36
Red Wattlebird	*Anthochaera carunculata*	0.26	0.52	0.52	0.11	0.36
Red-backed Kingfisher	*Todiramphus pyrrhopygius*		0.01		0.05	
Red-capped Robin	*Petroica goodenovii*	0.07	0.11	0.25	0.05	0.55
Red-lored Whistler	*Pachycephala rufogularis*	0.1				
Red-rumped Parrot	*Psephotus haematonotus*		0.01	0.04		0.36
Regent Parrot	*Polytelis anthopeplus*	0.08	0.05			
Restless Flycatcher	*Myiagra inquieta*	0.03	0.14	0.05	0.16	0.18
Rock Dove	*Columba livia*					0.09
Rufous Whistler	*Pachycephala rufiventris*	0.05	0.06	0.11		
Shy Hylacola	*Hylacola cauta*	0.41	0.03	0.29		0.09
Silvereye	*Zosterops lateralis*	0.02		0.05		
Singing Honeyeater	*Lichenostomus virescens*	0.03	0.04	0.09	0.32	0.27
Southern Scrub-robin	*Drymodes brunneopygia*	0.38	0.08	0.52		0.27
Southern Whiteface	*Aphelocephala leucopsis*	0.02	0.07	0.05	0.16	0.09
Spiny-cheeked Honeyeater	*Acanthagenys rufogularis*	0.41	0.33	0.54		0.36
Splendid Fairy-wren	*Malurus splendens*	0.28	0.1	0.11		
Spotted Harrier	*Circus assimilis*			0.02		0.09

Common Name	Species	Landscapes				
		Billiatt	Holder	Karoonda	Loxton	Pinnaroo
Spotted Nightjar	*Eurostopodus argus*	0.02	0.02	0.04		
Spotted Pardalote	*Pardalotus punctatus*	0.93	0.79	0.77	0.26	0.55
Striated Grasswren	*Amytornis striatus*	0.11				
Striated Pardalote	*Pardalotus striatus*	0.16	0.55	0.46	0.84	0.18
Striped Honeyeater	*Plectorhyncha lanceolata*		0.02			
Stubble Quail	*Coturnix pectoralis*		0.02	0.11	0.05	0.36
Superb Fairy-wren	*Malurus cyaneus*					0.09
Swamp Harrier	*Circus approximans*					0.09
Tawny Frogmouth	*Podargus strigoides*	0.02	0.09	0.09		
Tree Martin	*Petrochelidon nigricans*	0.11	0.18	0.04	0.42	0.09
Varied Sittella	*Daphoenositta chrysoptera*	0.03	0.19	0.09	0.11	0.18
Variegated Fairy-wren	*Malurus lamberti*	0.25	0.24	0.39	0.05	0.45
Wedge-tailed Eagle	*Aquila audax*	0.05	0.01	0.09	0.11	
Weebill	*Smicrornis brevirostris*	0.97	0.8	0.57	0.58	0.27
Welcome Swallow	*Hirundo neoxena*		0.02	0.07	0.16	0.18
Whistling Kite	*Haliastur sphenurus*			0.02	0.05	
White-backed Swallow	*Cheramoeca leucosterna*		0.06			
White-breasted Woodswallow	*Artamus leucorhynchus*				0.05	
White-browed Babbler	*Pomatostomus superciliosus*	0.39	0.24	0.75	0.21	0.55
White-browed Treecreeper	*Climacteris affinis*		0.01			
White-browed Woodswallow	*Artamus superciliosus*	0.05	0.14	0.05	0.21	0.64
White-eared Honeyeater	*Lichenostomus leucotis*	0.74	0.38	0.38		0.27
White-fronted Chat	*Epthianura albifrons*		0.02	0.11		0.55
White-fronted Honeyeater	*Purnella albifrons*	0.26	0.18		0.05	0.09
White-winged Chough	*Corcorax melanorhamphos*	0.11	0.49	0.52	0.26	0.27
White-winged Triller	*Lalage sueurii*	0.03	0.05	0.29		0.64
Willie Wagtail	*Rhipidura leucophrys*	0.18	0.54	0.52	0.53	0.64
Yellow Thornbill	*Acanthiza nana*	0.02		0.29		0.55
Yellow-faced Honeyeater	*Lichenostomus chrysops*			0.04		
Yellow-plumed Honeyeater	*Lichenostomus ornatus*	0.49	0.77	0.29	0.37	0.18
Yellow-rumped Thornbill	*Acanthiza chrysorrhoa*	0.08	0.15	0.45	0.53	0.73
Yellow-throated Miner	*Manorina flavigula*		0.36	0.2	0.89	0.09
Zebra Finch	*Taeniopygia guttata*			0.04		