The impact of artificial watering points on rangeland biodiversity: A review

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**Executive summary**

This report describes the effects artificial watering points have on rangeland systems and their biota in Australia. One of the recent concerns regarding the large-scale spread of artificial watering points has been the effect that the increase in grazing pressure surrounding these focal points has on rangeland biodiversity. The loss of biodiversity in these regions has been attributed to the decline in landscape function as a result of human induced disturbances. As grazing pressure increases around these focal points, landscape function declines considerably, with a loss in vegetation cover, an increase in erosion, and a decrease in nutrient cycling.

Literature on the effects of grazing pressure surrounding artificial water sources was reviewed according to three main topics of interest.

1) The patterns displayed within the piosphere:

These patterns can be highly variable depending on grazing behaviour and forage conditions, the presence of fences, soil type, the salinity of water and climatic variables. A number of monitoring indices have been suggested; however, as there appears to be no universal pattern to the piosphere, researchers have been unable to agree on monitoring systems.

2) The degradation process, including soil compaction and erosion, and the effects on fauna and flora composition:

Soil erosion increases significantly within the first 2–3 km from water as a result of heavy traffic and vegetation stripping. A significant loss of functionality in this region alters the vegetation dynamics. This includes a decline in abundance and richness of palatable forage species. Feral herbivore species have increased in abundance, contributing to the pressure exerted within these regions. Native fauna species have mostly suffered declines as a result of increased pressure and habitat alterations.

3) Biodiversity monitoring:

This section covers more recent monitoring practices including remote sensing techniques and the use of Bayesian belief network models. These methods can monitor large areas and account for both temporal and spatial variation. Bayesian belief models can incorporate both empirical data and that of expert opinion, and can predict the response of a system to human disturbance. Both these models can be incorporated to produce a powerful monitoring tool.
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1. Introduction

1.1 Background and history

Over 70% of Australia's mainland consists of arid and semi-arid rangelands (James et al. 1999). This includes a diverse group of relatively undisturbed ecosystems such as tropical savannas, woodlands, shrublands and grasslands that harbour much of the country’s most distinctive fauna and flora (James et al. 1999, Woinarski and Fisher 2003, Smyth and James 2004). With the increase of human-induced disturbances following the settlement of pastoral grazing lands, management of rangeland biodiversity has become a real concern. Thirteen percent of Australia’s rangeland is degraded, 16% is affected by erosion, 17% is affected by woody weeds, and 25% of land cover is significantly disturbed (Smyth & James 2004). Pastoralism, altered fire regimes, the spread of pests and exotic species, and changes in water availability have been identified as the main contributors to this degradation (Woinarski and Fisher 2003). One of the more recent and pressing concerns regards the spread of artificial watering points. How the concentration of livestock around water points affects the biodiversity and sustainability of rangelands has been debated for years, with the development of many indices to monitor the process. No monitoring scheme has yet proven the most accurate and effective in determining the impact of grazing pressure around water points.

Prior to European settlement, the biota of Australia’s arid and semi-arid rangelands was adapted to long periods of dry conditions. Advantage was taken of annual rainfall and the formation of temporary water sources, with significant fluctuations in abundance and distribution following seasonal rains. Flora richness and abundance usually responds well to rainfall, with the return of annual short lived forbs (Phelps 1999). Fauna species display similar correlations to the presence of rain, irrupting in abundance and extending in distribution.

The grazing potential of rangelands was recognised early in the 19th century for their ability to support sustainable and hardy pasture species, and grazing leases were released over much of eastern and southern Australia. Early grazing was dependent on water availability, and was predominately concentrated around permanent and semi-permanent water sources of the major waterways (James et al. 1999). Following the discovery of the Great Artesian Basin, large numbers of artificial water sources in the form of troughs, dams and bores were established by the 1950s (James et al. 1999). This extended the available grazing land to water-dependent livestock, and stocking rates intensified significantly. Today, artificial water sources are found at high densities throughout Australia’s grazing rangelands, with an average distance between points of less than 10 km (James et al. 1999).

The uneven distribution of cattle and grazing intensity has been recognised as a dominant problem since the 1920s (Lamon 1927, 1977 cited in Low et al. 1980) and a key threat to rangeland biodiversity (Pringle and Landsberg 2004). An important facet of biodiversity is the array of services it provides to the ecosystem. This includes gaseous compositions, amelioration of climates, fertility and stability of soils, disposal of wastes, cycling of nutrients and the natural control of pathogens and parasitic organisms (West 1993). This delicately balanced system supports an array of fauna and flora compositions and assists in the ability to deal with catastrophic events. Any disruption or alteration to this system will unbalance the production of the entire ecosystem, reducing its resistance to dramatic events. The loss of biodiversity can influence both the quality and quantity of ecosystems, while creating economic disruption (West 1993). Australia's rangelands are heavily used as grazing lands, with strong economic inflows. Cattle and calf production generate $4.4 billion per year, while wool, sheep and lamb production generate $1 billion each year (Australian Collaborative Rangeland Information System 2001). Any alteration in the functional ability of these systems may reduce rangeland productivity, causing economic declines of a short-term or long-term nature depending on the scale of disruption.
1.2 Aims

The aim of this review is to synthesise information on the effects of artificial watering points on rangeland systems and their biota within Australia. Literature on the effects of grazing pressure surrounding water sources will be reviewed according to three main topics of interest. These are:

- 1) the patterns displayed immediately surrounding the water source and the indices used to measure these patterns
- 2) the degradation processes including the effects on fauna and flora composition
- 3) monitoring possibilities using remote sensing techniques and Bayesian models.

1.3 Chapter summary

- A large proportion of Australia consists of arid and semi-arid rangelands where the sustainability of biodiversity has become a real concern.
- Water points in rangelands have reached high densities since the discovery of the Great Artesian Basin.
- Today, the average distance between water points is less than 10 km.
- With the provision of water, livestock densities and distribution have increased significantly.
- Grazing pressure is a key threat to the loss of rangeland biodiversity, influencing the quality and the quantity of the ecosystem.
2. Key concepts

2.1 Disturbance

A disturbance, as defined by White and Pickett (1985), is any relatively discrete event in time that disrupts ecosystem community or population structure and changes resources, substrate variability, or the physical environment. Disturbances can be highly variable and include differences in scale, type, frequency, intensity and duration (McAlpine 1997). The state of the vegetation mosaic is often indicative of this variation in disturbance.

2.2 The piosphere

Osborn et al (1932) was the first in Australia to document the radial symmetry in grazing intensity that develops around watering points, and in 1969 Lange termed this grazing pattern ‘the piosphere’ (James et al. 1999). The central idea of the piosphere is that within large areas of pasture, the impact of livestock distribution in relation to water is patterned. Although the original term was based on the radial patterns extending from the focal water point, it has since been recognised that these patterns can be highly variable and depend not only on the behaviour of the animals, but also on the number of animals with or without free movement (Andrew 1988). This report will document the pattern variation observed within the piosphere and the factors that produce these responses.

2.3 Landscape function

This evaluates the biophysical processes that take place within a landscape. Healthy landscapes maintain the ability to retain water, soils, nutrients and organic matter. Vegetated areas act as obstructions to water flows and tend to support a richer and more productive flora composition (Ludwig 2004).

2.4 Functional integrity

A landscape with greater vegetation cover and richness often indicates good functional integrity and subsequently greater fauna and flora biodiversity (Ludwig 2004). Functional integrity measures the intactness of soil, native vegetation patterns and the processes that maintain these patterns (Ludwig 2004).

2.5 Resistance

In this report, resistance refers to the ability of flora species to survive grazing or browsing activity. Grazing resistance can be related to plant anatomy, chemistry or physiology and can be divided into avoidance or tolerance responses. Avoidance responses reduce the impact of grazing pressure by the species declining significantly in heavily grazed locations. Tolerance responses promote active growth following extensive grazing periods. The most grazing resistant plants are grasses, followed by forbs, deciduous shrubs and trees and evergreen shrubs and trees (Lyons & Hanselka nd).

2.6 Resilience

Resilience of pasture is an ability to respond to an outside pressure, shown by a strong tendency to return to its original state once the pressure has been lifted. The response changes are not fundamental to the functional ability of the system (Walker & Noy-Meir 1982).
2.7 Degradation

Land degradation refers to the undesirable changes in plant composition, soil and land surface characteristics. Land degradation in response to grazing practices in Australia’s rangelands has accelerated, with serious concerns regarding soil erosion and significant changes in vegetation composition (Bastin & James 2002). Substantial degradation can be observed with increasing proximity to water.
3. Patterns and indices

3.1 The variability in piosphere patterns

Livestock are limited in the distance they can travel due to their dependence on water (Foran 1980, James et al. 1999). Grazing impact is therefore significantly greater surrounding watering points within rangeland communities. It was originally perceived that in relatively uniform landscapes, such as chenopod shrublands, a radial grazing pattern representative of livestock movement would be observed (Lange 1969, Andrew 1988). Based on this idea of radial symmetry, the sacrifice zone immediately surrounding the water source was termed the piosphere (Figure 1). It has since been recognised that these grazing patterns can be highly variable and piospheres in the traditional sense are usually ‘warped’ by the presence of fences, grazing preferences, the salinity of water, climatic variables, and the availability of permanent and temporal water sources (Pringle & Landsberg 2004, James et al. 1999, Bastin & James 2002). These radial patterns become distorted into star shapes with axes of concentration extending into those landscape types that are preferred by the grazing animal (Pickup et al. 1998).

Differences exist in grazing behaviour between livestock species. This contributes to the uneven grazing pressure that spans the sacrifice zone. Sheep graze head first into prevailing winds and high temperatures reduce sheep grazing to just 3 km from a water source (Lange 1969). This pattern of behaviour increases the grazing pressure closer to the water source and in the direction of prevailing winds (Orr 1980). Wet conditions and lower temperatures permit foraging away from water points for extended periods of time. During this time sheep are dependent on ephemeral water and forage moisture (James et al. 1999) and grazing pressure extends further out from the water source.

In favourable forage conditions, cattle will graze just 3–4 km from a water source, and display a preference for riparian vegetative communities by grazing the same patch for hours (Hodder & Low 1978, James et al. 1999). Forage preferences may be altered in response to rainfall, and in drier conditions grazing distances may extend to 10 km (Low 1972 cited in Low et al. 1980). Water points act as the primary controlling factor in the distribution of cattle, with a ‘faithfulness’ displayed to a particular water point (Low et al. 1980, Hodder & Low 1978). This means repeated visits to the one water point, with the carving of distinctive tracks to and from that water source. Saline water and the presence of fences may also limit the distances livestock move from water. Saline conditions would increase the number of return visits, while the presence of fences reduces the area available for grazing, thus increasing the pressure observed within the piosphere. Each of these factors causes substantial variation within the piosphere (James et al. 1999) making monitoring processes difficult.
3.2 Monitoring indices

As there appears to be no universal response to the impact of grazing on biodiversity, researchers have been unable to settle on adequate management solutions and monitoring schemes. The theory of non-equilibrium behaviour displayed within the rangeland system explains the variations observed in vegetative responses to rainfall and grazing influences on a spatial scale (DeAngelis and Waterhouse 1987 cited in Pickup et al. 1998). This theory considers the resilience and resistance of vegetative species and how they vary according to grazing pressure. Some species may be more tolerant to grazing pressures, and respond well to rainfall, while others may be restricted to water remote locations (Figure 2). This variable behaviour makes it difficult to determine whether land is continuing to degrade, remaining stable or improving (Pickup et al. 1998).
A number of indices have been used in an attempt to describe the grazing gradient that extends from the water point. These include density of herbivore tracks (Figure 3) (Pringle & Landsberg 2004), responses in vegetative cover (Figure 4) (Li & Reynolds 1993, McGarigal & Marks 1995, Ludwig et al. 1999, Bastin & James 2002), density of faecal matter (Figure 5) (Ludwig et al. 1999), and percent cover (Figure 6) (Graetz & Ludwig 1978).
Figure 4: The linear distance of landscape patches (#/100m of line) with distance from water (km)
For: (a) eucalypt savannas, Kidman Springs and (b) Mitchell grasslands, Mount Sanford, Northern Territory. Also illustrated is the cover of patches (%) for: (c) Kidman Springs and (d) Mount Sanford, and the total obstruction widths for patches (m/100m) for: (e) Kidman Springs and (f) Mount Sanford. (Ludwig et al. 1999).

Figure 5: Attributes of recent cattle grazing in relation to distance from water
Graphs show dung-pats on (c) Kidman Springs and (d) Mount Sanford sites, Northern Territory (Ludwig et al. 1999).
The sigmoid curve can be described by a logistic equation with parameters for an upper asymptote $K$, a lower asymptote zero, and a slope $b$. The curve is symmetrical about an inflection point $GF$. $GF$ is the point of symmetry and points $EG$ and $FP$, which are points of maximum slope change (Graetz and Ludwig 1978).

Each of these indices provides a correlation between grazing pressure and loss of functionality. Most of these correspond to the amount of time spent in a location and are unable to account for temporal variation. They do not accurately reflect the direct and present damage to the current system (Andrew 1988). For example, track density may be indicative of a past stocking rate and not attributable to the current grazing practices.

Vegetative indices such as the contagion index, interspersion index, and the inflexion index measure the response in vegetation cover and are more accurate in determining spatial and temporal variation. The contagion index (Li & Reynolds 1993) measures the clumping or dispersion (patchiness) of the landscape. The interspersion index (McGarigal & Marks 1995) indicates the intermixing of patches, while the inflexion index measures the extent to which vegetation is restored following good rainfall and describes the extent of grazing damage (Bastin & James 2002). The longer a system takes to return to its natural state, the greater the damage.

3.3 Chapter summary

- Livestock movement is dependent on water, thus grazing impacts are often greatest around water sources.
- The grazing patterns observed within the piosphere can be highly variable and are dependent on the differences in livestock grazing and drinking behaviour, water condition, and the presence of fences.
- A number of indices have been used to describe the grazing gradient, providing a correlation between grazing pressure and loss of functionality. Most of these indices are unable to account for the temporal variation in vegetation responses.
- Vegetative indices may be more accurate in monitoring grazing pressures.
4. Degradation processes

4.1 Soil compaction and erosion

Heavy stock trafficking areas within the first 2–3 km of a water source severely affects the soil stability. Soil erosion increases in these areas as result of vegetation stripping and heavy trampling (Landsberg et al. 1997, James et al. 1999), while livestock tracks intensify the natural drainage patterns and exacerbate the natural erosion process (Pringle & Landsberg 2004). Most nitrogen available to plants in rangeland soils, is held within the top 10 cm of the soil due to the breaking down of organic matter. Nitrogen-fixing algae are found in the cryptogamic crusts. Heavy trampling and vegetation removal breaks this crust, creating an unstable soil surface that is vulnerable to wind and water erosion. Regeneration of vegetation is also hindered by the removal of this nutrient rich soil layer (James et al. 1999).

Soil erosion in rangelands can seriously affect the productivity of the system. Sheet erosion involves the uniform removal of soil over large areas as a result of wind or water (Carey & Silbum 2006). This form of erosion is not always obvious, and results in the loss of productive soil. In some cases, the topsoil may be totally removed leaving a scalded surface layer.

4.2 Loss of landscape functionality

Erosion results in the loss of productive and nutrient rich topsoils. These scalded areas are more susceptible to higher temperatures, have lower porosity and less microbial activity (Carey & Silbum 2006) and often result in a subsequent decline in functional integrity. Higher rates of run-off occur in these areas, reducing the infiltration and nutrient cycling of the system (Figure 7) (Ludwig 2004). This loss in soil moisture and nutrients reduces the resilience of a system and its ability to deal with catastrophic events. The loss in functional integrity has been identified as one of the likely causes of extinctions and drastic declines in native flora, small mammals and granivorous birds (Woinarski 1999 cited in Ludwig 2004). This occurs as a result of the loss or alteration of habitat, shelter, and availability of food. With the removal of vegetation, fauna in these scalded areas may become more exposed to feral and native predators.
Figures 7A and B: Photographs displaying the differences in functionality at two sites in Crows Nest, QLD.

Figure 7A displays a landscape of high functionality: a) dominated by trees and large perennial grass tussocks, b) complex litter on the landscape surface, and c) soil under a tussock with crumb structure and open fabric. Figure 7B displays a location with much poorer functionality with: a) trees cleared to the creek line, b) greatly reduced litter and ground cover and c) soil with a massive crusted structure (Ludwig 2004).
4.3 Effects of other herbivores

The primary reason for the establishment of large numbers of artificial watering points in arid rangelands has been to support domestic livestock. An adverse affect of this has been the increase in water dependent herbivores other than livestock. The increase in the distribution and abundance of feral animals such as goats, pigs, camels, horses and donkeys, rabbits and cats is well documented (Landsberg et al. 1997, James et al. 1999). Macropods have also benefited greatly from the provision of water, and abundance of many species has increased dramatically. These animals are not restricted by fences, and grazing pressure exerted by kangaroos often matches that of livestock (Pringle & Landsberg 2004, McAlpine et al. 1999). The impact of these water dependent herbivores on the piosphere depends on individual grazing preferences, drinking behaviour and the animals’ ability to easily reach water supplies (presence of fences, the closing of water points, Finlayson troughs etc). These variations in grazing preferences and behaviour also contribute to the uneven grazing pressure that spans the sacrifice zone.

Competition for pasture between some herbivores has become a concern, and flora species that may otherwise escape domestic livestock pressure now incur heavy grazing pressure exerted by other herbivores. Kangaroos display strong preferences for particular vegetation types, with little overlap with that of domestic livestock (Landsberg & Stol 1996), and grazing by these animals can greatly retard vegetation growth even in the absence of other livestock (Hacker & Freudenberger 1997).

Rabbits have a profound effect on vegetation structure and significantly degrade the vegetation within the piosphere. Although rabbits obtain moisture from their diet and don’t depend on water sources, perennial grasses are often replaced by annuals as a result of intensive rabbit grazing and erosion caused by their burrowing (Hall & Lee 1980).

Feral goats have a wide dietary tolerance and contribute between 3 and 30% of the total grazing pressure in south-western Queensland (Thompson et al. 2002). Australia’s rangelands support 0.5–2 million goats in New South Wales, Queensland, South Australia and Western Australia (Pople et al. 1996 cited in Edwards et al. 2004). Goats inflict considerable damage to perennial vegetation while competing with domestic livestock for water and pasture (Edwards et al. 2004). They are also capable of grazing unstable, rocky areas that may otherwise provide a refuge for grazing sensitive flora (James et al. 1999). Camels, horses, donkeys and pigs also compete with livestock for forage, contribute to soil erosion, and foul and damage waterholes (Edwards et al. 2004).

4.4 Chapter summary

- Heavy livestock traffic severely affects the stability of the piosphere, particularly within in the first 2–3km from the water source.
- The removal and breakdown of the surface crust increases the erosion produced by wind and water. This removal of the nutrient rich topsoil severely affects the functional integrity of the area, and reduces the biodiversity.
- Livestock compete with other water dependent feral and native herbivores for both water and forage, increasing the grazing pressure exerted within this region.
- Macropods increase significantly in number with the provision of water and affect the grazing gradient significantly.
- The impact these animals have on the grazing gradient depends on grazing preferences, drinking behaviour and the ability to easily reach water.
5. Floristics of the piosphere

5.1 The major impacts

One of the most documented approaches to studying the effects of grazing in rangelands has been to examine the changes in flora species composition, abundance and community structure along the grazing gradient, varying from a few hundred meters to several kilometres around an artificial water source (Foran 1980, Fusco et al. 1995, Landsberg et al. 1997, Ludwig et al. 1999, Bastin & James 2002, Landsberg et al. 2003, Ludwig 2004). A number of general patterns have emerged:

- The piosphere is often degraded as a result of heavy livestock use, leading to a decline in landscape functionality and an increase in dung and urine within these zones.
- This alters the vegetative dynamics of the piosphere considerably. This zone may be bare during dry conditions, and support short–lived, unpalatable and ‘trample resistant’ species following rain (James et al. 1999).
- There is often a zone of unpalatable woody weeds beyond the denuded area surrounding water. Martin and Ward (1970, in Ludwig et al. 1999) found that this zone dominated the region within 500m from water. Substantial changes in species composition and vegetative cover occur within this zone, with a decline in abundance and richness of palatable forage species (Figure 8). These ‘decreaser’ species are mostly native species, and significantly outnumber those that increase within the piosphere (Landsberg et al. 2003).

Short term results of this change in vegetation composition include the loss or alteration of flora species, while long term changes include the irreversible alteration of habitat from arid zones into mallee savanna habitats and the restriction of grazing intolerant species to water remote locations ( Bastin & James 2002)

5.2 Variability in responses

The degree of pressure exerted on rangeland vegetation varies greatly with pasture type, distance and direction from water, grazing behaviour, and seasonal variation. If grazing were uniform we would observe zones of different vegetation conditions forming annuli around the water points (Foran 1980).

It has been documented that grazing at moderate levels improves species richness and pasture productivity (Orr 1975). Heavy grazing, however, severely impedes the regenerative ability of native pasture species and results in a decline in species richness (James et al. 1999, Orr 1975). Some species may display more of a gradual decline in their abundance, while others may be removed from the area altogether, only to be found in water remote locations ( Bastin & James 2002). These areas may become valuable regions of plant diversity supporting grazing sensitive species (Landsberg et al. 2003).

A number of indices have been proposed to describe the variation in flora responses to grazing pressures over both temporal and spatial scales. These include the contagion index (Li & Reynolds 1993), the interspersion index (McGarigal & Marks 1995) and the inflexion index (Bastin & James 2002). Systems with a higher proportion of palatable forage are most intensively stocked as a result of this productivity. These systems usually incur higher index values and are most adversely affected by grazing ( Bastin & James 2002). Alternatively, a higher contagion index for areas of lower productively indicates less patchiness and less intermixing, which signifies non- degraded areas (Bastin & James 2002). The interspersion index for both the land system and vegetation type are also lower for the non-degraded areas compared with the total grazing area. These results indicate homogeneity within the non-degraded locations, attributable to a higher proportion of pastorally less-productive land systems or vegetation types. These systems display minimal grazing impact and return to complete recovery following rainfall.
5.3 Regional variability

Australia’s arid rangelands consist of four main types of vegetation: spinifex on gibber plain, salt bush steppe, Mitchell grass tussocks and mulga shrublands. The latter two have been severely affected by grazing practices (Davies 1977). The most pastorally productive vegetation types include open woodland plains, alluvial fans and plains and floodouts, and are often the most degraded in terms of poor vegetation recovery following rainfall (Table 1). Mulga shrublands, hills and foothills, and salt lakes are less pastorally productive and display almost full recovery following rainfall (Bastin & James 2002).
Table 1. Area and extent of land degradation for land systems grouped into vegetation types
Vegetation types are arranged in order of decreasing pastoral productivity (based on stratification of land systems used by Bastin et al. 1993). The ‘distance to inflexion point’ indicates that distance from water beyond which complete recovery in wet period vegetation cover occurred. %CPL (percentage of Cover Production Loss) values were assigned to the same categories of land degradation. (Bastin & James 2002).

<table>
<thead>
<tr>
<th>Past. Prod.</th>
<th>Vegetation type</th>
<th>Area (km²)</th>
<th>Dist. to infl. point (km)</th>
<th>%CPL value</th>
<th>Land degradation cat.</th>
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<tbody>
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<td>alluvial fans &amp; plains (open woodland)</td>
<td>1215.1</td>
<td>6.6</td>
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<td>severe</td>
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<tr>
<td></td>
<td>floodouts</td>
<td>920.8</td>
<td>6.2</td>
<td>16</td>
<td>severe</td>
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<tr>
<td></td>
<td>cracking clay plain</td>
<td>54.3</td>
<td>5.0</td>
<td>13</td>
<td>high</td>
</tr>
<tr>
<td>High</td>
<td>floods with open woodland</td>
<td>325.0</td>
<td>5.6</td>
<td>50</td>
<td>severe</td>
</tr>
<tr>
<td></td>
<td>calcareous slopes &amp; plains</td>
<td>4487.8</td>
<td>3.4</td>
<td>3</td>
<td>slight</td>
</tr>
<tr>
<td></td>
<td>granitic plains–open woodland</td>
<td>1343.8</td>
<td>5.0</td>
<td>8</td>
<td>moderate</td>
</tr>
<tr>
<td></td>
<td>sattbush &amp; myall</td>
<td>384.5</td>
<td>4.6</td>
<td>17</td>
<td>severe</td>
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<tr>
<td></td>
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<td>4.6</td>
<td>5</td>
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<td>2.4</td>
<td>1</td>
<td>slight</td>
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<td>foothills, footslopes, colluvial fans &amp; plains</td>
<td>942.8</td>
<td>2.6</td>
<td>2</td>
<td>slight</td>
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<td></td>
<td>southern mulga type</td>
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<td>7.2</td>
<td>16</td>
<td>severe</td>
</tr>
<tr>
<td>Low</td>
<td>sand dunes &amp; plains</td>
<td>14901.8</td>
<td>1.0</td>
<td></td>
<td>inverse</td>
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<td></td>
<td>salt lakes</td>
<td>354.0</td>
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<td>slight</td>
</tr>
<tr>
<td></td>
<td>hills &amp; ridges</td>
<td>464.8</td>
<td>1.6</td>
<td>1</td>
<td>slight</td>
</tr>
<tr>
<td></td>
<td>mulga shrubland</td>
<td>3395.9</td>
<td>1.8</td>
<td>0</td>
<td>nil</td>
</tr>
<tr>
<td></td>
<td>mulga terraces</td>
<td>144.3</td>
<td>3.2</td>
<td>5</td>
<td>moderate</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>34497.9</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Biomass and palatable shrub species have shown to decrease rapidly within the zone of 0–400m from water in chenopod shrublands (James et al. 1999) and the dominant perennial shrub species (Atriplex and Maireana spp) are replaced by annual chenopod subshrubs, forbs or annual grasses (Osborn et al. 1932, Graetz & Ludwig 1978). Species richness in these areas does not seem to vary consistently with distance from water (James et al. 1999).

A major shift in the composition of understorey vegetation has been identified within Acacia dominated woodlands and shrublands. The palatable perennial grasses (Thyridolepis mitchelliana and Themeda australis) are replaced by unpalatable species such as Aristida species. Heavy and sustained grazing of pasture may deplete the seed bank, which leads to local extinctions (Hodgkinson 1992 cited in James et al. 1999).

Unpalatable native shrubs such as Eremophila, Senna, Dodonaea and Acacia species have begun to dominate acacia woodlands (James et al. 1999). These shrubs remove valuable nutrients and moisture from the soils, preventing grasses from re-establishing. Vegetation composition and cover along the gradient undergo major changes, showing a decrease in ground cover with increasing distance to water (Foran 1980, James et al. 1999).

Annual grasses appear to dominate the zones closer to water within the Mitchell grasslands. The perennial grasses (Astrebla spp) increase with distance from water and tolerate moderate to light grazing intensity, displaying a large degree of resilience (Orr 1980). The lightly grazed sites or those exclosed to grazing support a greater number of perennial species, higher than average percentage of ground cover and a greater cover pattern of diversity than sites closer to water (Orr 1980).
5.4 Chapter summary

- A number of patterns have been identified in vegetative responses to grazing pressure within the piosphere: the piosphere is degraded with a loss of functionality; the vegetation dynamics are altered, with bare ground during dry conditions followed by short-lived unpalatable forage following rain; and a zone of unpalatable woody weeds dominates beyond the denuded zone. This area sees a decline in abundance and richness of palatable forage.
- There is a large degree of variation observed in vegetative responses as a result of pasture type, distance and direction from water, grazing behaviour and seasonal variation.
- The contagion index, interspersion index and inflexion point have been used to measure grazing pressure with distance to water. Regions with higher productivity incur higher index results.
- Regional variation in vegetation responses occurs as a result of varying tolerance levels to grazing pressures.
- The most pastorally productive systems are woodland plains, alluvial fans and plains and floodouts. Systems that are most severely affected by grazing practices are mulga shrublands and Mitchell grasslands.
6. Fauna of the piosphere

6.1 Native versus feral animals

The increase in feral species surrounding water sources has been well documented. These animals increase in abundance and distribution with the provision of water, often competing with livestock for forage and water supplies. What is unknown is the response of native fauna species to the presence of artificial water points.

Australia’s rangelands are unique systems that support an abundance of native fauna species, each adapted to long periods of dry conditions. Reptile and mammal species find shelter in vegetation and cracks produced in soils to avoid extreme temperatures, and often irrupt in abundance and distribution following seasonal rainfall. Natural water sources and drainage lines (billabongs, clay pans, duricrusts) support an increase in biodiversity, and encourage the return of migratory birdlife (Ford 2001, Pringle & Landsberg 2004).

Although no reptile species are known to have become extinct in the arid and semi-arid zones of Australia, a number are listed as endangered or threatened and are disadvantaged by pastoral activities. The scincid species *Morethia boulengeri* and *Ctenotus regius* are associated with leaf litter in western New South Wales and where heavy grazing removes the ground cover, these species may be locally absent (James unpublished data). A weak trend of increasing reptile species richness with increasing distance from water in the Mitchell grasslands was found by Fisher (1996); however other authors (Smith et al. 1996) have found no effect on species richness (James et al. 1999).

Most authors report declines in the geographic range of birds in response to grazing pressure. In particular, ground dwelling birds of riparian and chenopod habitats have declined greatly. Granivorous birds are particularly listed as threatened bird species, with declines observed in the tropical and subtropical savannas and arid zones (Reid & Fleming 1992). Franklin (1999), reports that granivorous birds within tropical savannas are in a state of considerable flux. The paradise parrot (*Psephotus pulcherrimus*) has suffered significant range contraction and is probably extinct, while the golden-shouldered parrot (*Psephotus chrysopterigus*) has declined and is now considered endangered. The Gouldian finch (*Erythrura gouldiae*) is also endangered. Families most affected by grazing practices include pigeons, doves, finches and parrots (Franklin 1999).

While many native species have shown significant declines, some have also benefited as a result of available water. Temporary and replenished natural water sources support an increase in biodiversity, including water dependent and migratory birds (Ford 2001). The presence of water has significantly increased the abundance and distribution of emus (*Dromaius novaehollandiae*), which now exploit food sources from previously limited regions. Bourke’s parrot (*Neopsephotus bourkii*), once rare, is now common throughout the mulga zone. The crested pigeon (*Ocyphaps lophotes*), zebra finch (*Taeniopygia guttata*), and galahs (*Cacatua roseicapilla*) have also increased in abundance (Davies 1977, Noble et al. 1998). This increase in abundance and distribution is thought to be attributable to water and the clearing of land for grazing, which spreads seed sources.

Mammal species of Australia’s rangelands have also declined, with numerous extinctions among medium sized (35–5500g) animals in response to altered vegetative dynamics and grazing pressures (Davies 1977, James et al. 1999, Ludwig et al. 1999). The long haired rat (*Rattus villosissimus*) and Forrest’s Mouse (*Leggadina forresti*) of the Mitchell grasslands are good examples of species that irrupt in abundance in response to the onset of rains (Mifsud 1999). Both of these species are now listed as ‘vulnerable’ as a result of heavy grazing practices, the loss of suitable habitat through erosion and vegetation damage, and the introduction of feral species.

With the change in vegetation structure and the increase in water dependent herbivores, piospheres have become hunting and scavenging grounds for feral cats (*Felis catus*), foxes (*Vulpes vulpes*) and...
dingoes (*Canis lupus*) (James et al. 1999). Cats are capable of prey switching, and don’t display any strong correlations with the abundance of a particular food source. Typical densities for feral cats in rangelands extend from 0.1 to 0.6 animals/km², although densities as high as 6.3/km² have been recorded in the Mitchell grass downs (Edwards et al. 2004). There is no current published literature surrounding how these animals use water points and the types of prey most affected. It is thought, however, that cats may focus their hunting effort around water points where birds are an easy target. The diet of foxes is mostly mammalian carrion, but birds, reptiles and amphibians may also be targeted around water. Dingoes prey on kangaroos around water, while carcasses of sheep and cattle during drought periods help maintain dingo and fox populations (James et al. 1999).

More research is required to determine the effects artificial watering points and the increase in grazing pressure have on Australia’s native fauna. Many species have displayed drastic declines; others have indicated a tolerance, while some have benefited from the provision of water and the spread of seeds. It is unclear how these responses influence rangeland biodiversity.

### 6.2 Invertebrates

The few studies that have investigated invertebrate responses to increased grazing pressure are highly variable and depend on taxonomic level, season of sampling, nature of changes and vegetation composition (James et al. 1999). Ants are good indicators of taxa disturbance, as abundance and species richness appear to alter under varying grazing pressures. Their usefulness in monitoring grazing pressures, however, is still in its infancy (James et al. 1999). Spiders also display significant differences in abundance and richness between areas with varying grazing intensities; however responses also vary among families. Termite richness has shown no direct response to grazing, and termite mounds either increase or decrease with low to moderate levels of grazing (Watson et al. 1973, Braithwaite et al. 1988, both cited in James et al. 1999).

A study conducted by Ludwig et al (1999) found that grasshopper density decreased with decreasing distance to water. The study suggests strong linkages between landscape function, biodiversity and impacts of cattle grazing and trampling. The decline in grasshopper density most likely corresponded with that of a decline in flora cover and richness, indicating a loss in landscape function. These interactions displayed between plants, animal, soil and the landscape processes need to be better understood to achieve a balance between rangeland production and conservation (West 1993, Ludwig et al. 1999).

### 6.3 Chapter summary

- A large degree of uncertainty still surrounds the response of native fauna to the presence of water points.
- Reptile species are threatened and disadvantaged by pastoral activities.
- Most authors report declines in the geographic range of birds in response to grazing pressure. In particular, granivorous birds have suffered great declines.
- Other native bird species have benefited with the provision of water and the spreading of seed sources through pastoral activities.
- Most medium-sized mammals have declined with numerous extinctions observed in rangelands.
- The loss of habitat and vegetation, and the introduction of feral animals have had a significant impact on these animals.
- Little is known regarding the invertebrate community and its response to grazing pressures and results appear to be highly variable.
- A better understanding of fauna responses to the presence of water points is required to achieve a balance between rangeland production and conservation.
7. Ways forward

7.1 Biodiversity monitoring

Regular observations and monitoring are an integral part of management and may contribute to the understanding of how an ecosystem responds to a particular pressure, or can be used to analyse previous decisions and outcomes (Australian Collaborative Rangeland Information System 2001). For land managers, accurate information is required to make economic and ecologically viable decisions. In order to do this, managers need to be able to distinguish between the distribution of pressure, grazing induced change, seasonal fluctuations and other influencing variables (Pringle & Landsberg 2004). Monitoring processes established over the last 30 years have not always considered how these variables relate to production, biodiversity, society, economics and culture. These monitoring processes have generally consisted of ground-based data collection with a focus on pasture response to grazing domestic stock. Until now monitoring of biodiversity has received very little consideration (Australian Collaborative Rangeland Information System 2001, Smyth et al. 2003).

Recent discussions surrounding the suitability of current monitoring practices have acknowledged the need for adequate biodiversity programs that foster long term administration and public support (Smyth et al. 2003). The primary purpose of monitoring is to detect the magnitude and direction of change over long periods of time, not to establish causality. To monitor the sustainability and health of rangeland biodiversity, a number of values require consideration. These include composition (species, population, community and genetic), structure (habitat and landscape), function (functional processes, resilience, integrity and sensitivity to threats) and social perception (Smyth et al. 2003).

One method for assessing the relative condition of a system involves the use of biodiversity indicators. These indicators are a set of biotic, environmental, pressure and landscape attributes that best signal the effects of human-exerted pressures on biodiversity within the rangeland. Biotic response attributes include actual or derived measurements of biotic entities that are collected in the field using ground-based sampling techniques. They can be used to indicate the state or condition of biodiversity (species richness, the abundance of targeted species). Environmental attributes are biophysical measures of the environment (climate, topography, soil properties, vegetation or habitat characteristics) that can be measured in the field or remotely. These usually measure variables that drive biotic responses or can be used to derive landscape measures. Pressure attributes provide a measure of a threatening process caused by human activities that affect biota. The variables measured are likely to interactively affect environmental and biotic response attributes (e.g. extent and rate of clearing, change in human population density, abundance of foxes). Landscape attributes use remote-sensing techniques (satellite imagery, airborne photo/ videography, GIS mapping) and measure the environmental and pressure attributes of ecosystems at multiple spatial scales. These may be used as surrogate measures of biodiversity at broad scales (leakiness index, mapping of artificial water points, habitat complexity scores) (Smyth et al. 2003). A number of indicators may be required to accurately monitor the many dimensions of biodiversity including the trends observed in the variety of ecosystems, landscapes, flora and fauna of interest.

7.2 Monitoring with remote sensing

Vegetation indices, currently used to monitor the decline in vegetation and land functionality as a result of grazing pressure, presume that the relationships between an index and vegetation cover remain constant over time (Pickup et al. 1993). This is rarely the case and suitable indices are needed to recognise both spatial and temporal variability. Pickup (1989) described how grazing induced degradation can be separated from natural variability in the landscape, and short term change due to rainfall, using spatial and temporal patterns of relative cover coupled with grazing distribution models. Pickup et al (1998) also argue that these consistent patterns of change over long periods in response to rainfall are more indicative of the true condition of the landscape, than the immediate response to major rainfall events.
A number of authors have proposed the use of Landsat Multispectral Scanner (MSS) as a means of identifying historical cover change within arid and semi-arid rangelands (Pickup et al. 1993, Karfs et al. 2000). Landsat satellite imagery provides information on vegetation responses to rainfall and allows an assessment of landscape function. Images may be selected based on climate or season history and can be used to provide a historical measure of vegetation cover and change over time (Australian Collaborative Rangeland Information System 2001).

The Audit Rangeland Implementation Project (Karfs et al. 2000) is one example of how remote sensing techniques may be implemented with the use of land resource property infrastructure, detailed monitoring sites, ancillary data, and with summaries of vegetation change derived from multi-scale Landsat Satellite data. These methods may be used to implement benchmarks and long-term operational rangeland monitoring systems. The method was trialed in Australia’s Tropical Savannas a project titled ‘Landscape Cover Change Analysis’ (LCCA), and holds the potential for further development within other rangelands systems (Karfs et al. 2000). The method is based on statistical brightness and trends through time of indices related to vegetation cover, and is used to infer land condition and to identify change within the landscape (Karfs et al. 2000). Additional outputs include temporal satellite datasets, basic stratification of land resources, identification of problem areas and their history, data on vegetation cover trends, coordinated monitoring databases derived from satellite and ground-based monitoring, increased knowledge of landscape processes and their responses to variable seasons, fire, and grazing impact and the consequences on biodiversity (Karfs et al. 2000).

Pickup et al (1993) also discussed the use of three basic approaches to vegetation cover estimation from Landsat MSS – mixture models, calibrated cover radiance relationships, and generalised vegetation indices. Mixture models separate green vegetation components, but are unsuitable for the dry components often found in arid and semi-arid rangelands. Cover radiance is derived empirically and provides absolute values for the percentage of vegetation cover. This can be costly and time consuming as data are collected through ground sampling (Pickup et al. 1998). Thirdly, generated vegetation indices provide information on the relative amount of cover present and relative changes that occur over time, rather than absolute values. The use of this data, however, is based on the assumptions that these correlations remain stable over time (Pickup et al. 1993), which rarely occurs.

One approach to estimating vegetation cover changes over time has been suggested by Graetz and others (Graetz & Gentle 1982; and Graetz et al. 1983, 1986, all cited by Pickup et al. 1998). They present the theory of the soil ‘cover line’ that extends through shadow, litter and shrubs at low radiance values, compared with bright bare soil at higher values. An increase in vegetation cover (unless green) shifts data towards the soil line (Pickup et al. 1993). While this may be adequate for single rangeland types, comparisons are unable to be made between rangelands, due to variations in soil radiance and vegetation brightness. The PD54 index (Pickup et al. 1993) is derived from the radiance properties of soil and vegetation that form a triangular structure in the four-dimensional Landsat MSS data space. The data space limits are described as the slope of the soil line (indicating the upper limit of the soil band), its offset, and the perpendicular distance to the vegetation line (Figure 9). This index is capable of denoting different levels of cover, depending on the soil background characteristics, making it one of the better indices for rangelands (Pickup et al.1993).
Remote sensing is a good monitoring tool as image databases consist of objective and consistently processed data, it allows monitoring over a range of scales and environments, it can be integrated with ground data to detect change and identify function in rangelands, it is cost effective, and can be applied across large areas (Australian Collaborative Rangeland Information System 2001).

7.3 Monitoring with expert knowledge

To develop an adequate biodiversity monitoring system, it is necessary to identify the core factors that may be driving the change, identify the changes occurring and what significance these changes hold for the biodiversity values, and include people with relevant expertise (Smyth et al. 2003). With the use of hierarchical models it is possible to infer the transformation of a rangeland system as a result of human or climatic alterations, while considering the uncertainty associated with this change (Gelfand et al. 2006).

The uses of Bayesian belief network models are proving to be successful tools in ecological decision making and management practices. Bayesian models are compact hierarchical models with the ability to represent all of the environmental variables and human induced disturbances that may be present within a particular system at a particular point in time. The model provides the ability to collate all forms of data and information (both empirical and hypothesised from expert opinion) and formulates the most appropriate management strategy based on this available information. It determines the degrees of confidence we have in various possible conclusions, based on an obtained body of evidence. The primary advantage of the model is the ability to predict a response to a particular event and the ability to rerun the model with different alternatives and new assumptions (Taylor 2003).

A Bayesian belief network is composed of three core elements:

1) A set of nodes representing the variables within the system, each with a finite set of mutually exclusive states that can be either discrete or continuous.
2) A set of links representing the causal relationship between these nodes. Links follow the direction from cause to effect.
3) A set of probabilities for each node specifying the belief that a node will be in a particular state, according to the states of those nodes that affect it directly (its parents). This relationship is displayed in a conditional probability table and accounts for the uncertainty surrounding the problem under investigation (Cain 2001).

7.4 An example of the use of Bayesian belief network models: the Julia Creek dunnart project

The Julia Creek dunnart (*Sminthopsis douglasi*) is an endangered marsupial confined entirely to the Mitchell Grass Downs and Gulf Plains bioregions of north-western Queensland (Lees 1999). The distinctive cracking clay soils and the abundance of adequate ground cover produced by the Mitchell grasses form an essential component of this species habitat preference. It is thought that the extensive cracks formed in dry, ashy, clay soils provide protection and shelter from extreme temperatures and predation by native and feral animals. As these soils become waterlogged with the onset of heavy rains, new grasses and forbs continue to provide this animal with shelter (Woolley 1992).

A number of threatening processes have contributed to the decline of this species. These include climatic factors, inappropriate grazing and land use pressures, and the impact of feral predators (Lundie-Jenkins & Payne 2002). The invasion of prickly acacia (*Acacia nilotica*) is also considered a significant threat as this weed competes with native vegetation, often resulting in a decline in cover and abundance of native species.

In a research project to identify and map the core areas of habitat critical to the survival of *S. douglasi*, a Bayesian belief network model was developed to represent the Mitchell grass system. This model was later linked to GIS data obtained for the region. Information relating to the key correlates within the Mitchell grass system was obtained from both empirical data and expert opinions. A number of experts were interviewed and surveyed and responses were used to build the model. The modeling program Netica (Norsys) was selected as the developing tool for the model. Netica has the ability to perform standard belief updating which solves the network by finding the marginal posterior probability for each node. A posterior probability is the likelihood that some parameter will be in a particular state, such as ground cover being low, given the input parameters, conditional probabilities and the rules governing how the probabilities combine (Marcot et al. 2001).

The states for each of the nodes along with the conditional probability tables were completed based on expert opinion. A number of government bodies provided GIS data for the main components of the system under investigation. This included land tenure, presence of water points, prickly acacia abundance, and soil and vegetation composition. This information was used to complete a map of the study location within the Mitchell grasslands.

Figure 10 shows the Bayesian belief network model for the Julia Creek dunnart. Although this model targets a specific species, it can be used across a range of fauna types, or may be used to display changes observed in floristic composition with distance from water points. The model can be altered on a case-by-case basis and can incorporate time scales in its output. Although some level of uncertainty surrounds the generated probabilities, these models are useful in expressing the likelihood of risk where uncertainty or bias may exist in expert judgment and where deficiencies exist in empirical data.

The information produced in this Bayesian output was used to map the likely distribution of the dunnart within the Mitchell grasslands. The Bayesian model was linked with the GIS data to produce maps of this rangeland system and the response of *S. douglasi* to the disturbances present within these locations.
Figure 10: The compiled network for the probability of dunnart occurrence in the Mitchell grasslands. Each node displays the probability of it falling into a particular state. For example, the probability that grazing pressure is low is 52.9% and that feral animal predation is medium is 62.8%. Based on these probabilities, the likelihood of that *S. douglasi* would occur in any locality is 24%.
7.5 Chapter summary

- Monitoring and regular observations play an integral part in management practices.
- Managers need to be able to distinguish between pressure, grazing induced change, seasonal fluctuations and other variables.
- To date, the monitoring of rangeland biodiversity has received little consideration.
- To adequately monitor this, the composition, structure, function and social perception of the ecosystem needs to be considered.
- Biodiversity indicators assist in the assessment of relative ecosystem condition. These include biotic, environmental, pressure and landscape attributes.
- Suitable indicators are needed that recognise spatial and temporal variation. Landsat MSS techniques have been proposed as a means of identifying historical change.
- Various approaches to the assessment of vegetation cover have been built on this technique, evaluating cover radiance, vegetation mixture and the development of various vegetation indices.
- The PD54 index was derived from the radiance properties of soil and vegetation and is used to indicate the different levels of cover depending on the soil characteristics.
- Expert knowledge is also helpful in the absence of adequate empirical data.
- Bayesian belief network models are useful in ecological decision making and management practices. They can predict the response of a system to a certain pressure, based on prior observations.
- An example of the use of this model is given for the Julia Creek dunnart in the Mitchell grasslands.
8. Conclusions

The establishment of artificial water sources since pastoral development in Australia’s rangelands has resulted in large-scale loss of biodiversity and landscape functionality. The number and spacing of artificial water sources across the arid and semi-arid zones dramatically alters the landscape. The piosphere is the zone that immediately surrounds the water source and provides a measure of increased erosion, loss of palatable forage and an increase in unpalatable woody weeds. These negative impacts decline with distance from the water source. Native and feral animal species have increased in geographic range and abundance as a result of water availability and contribute to the grazing pressure exerted in these regions.

A number of factors determine the degradation patterns observed within the piosphere. These include the species grazing preferences, drinking behaviour, ability of free movement, resistance and resilience of vegetation species, and seasonal fluctuations.

Although some native bird species have appeared to benefit from the provision of water and the spreading of seed sources in these arid lands as a result of grazing practices, most native fauna species have displayed significant declines in abundance and distribution. The loss of landscape functionality has been attributed to the large scale loss of biodiversity within rangelands.

It is difficult to monitor change in rangeland systems by human induced activity, due to the large areas involved and the limited availability of suitable empirical data (Bastin & James 2002). A number of monitoring indices have been proposed to measure this decline in functionality moving along the grazing gradient; however, most of these are unable to account for spatial and temporal variation. The development of remote sensing techniques (Pickup et al. 1993, Karfs et al. 2000, Bastin & James 2002) has provided the ability to monitor changes in vegetation cover across vast sections of rangeland and over varying intervals of time. Bayesian belief network models may also provide a management tool when suitable empirical data is lacking. This model incorporates both empirical data and expert opinion and provides the ability to predict the response of a particular system to human induced disturbances.

The concern regarding the spread of artificial watering points and the subsequent spread of grazing pressure is relatively new to Australia’s rangelands. Little empirical data is available regarding the loss of biodiversity within these regions, and although a number of negative speculations have been made, surprisingly little is known about the effects on biota (Landsberg et al. 1997). To date there is no agreed method for determining the effects grazing pressure has on biodiversity, nor the best approach to managing this. This review discussed the current knowledge about the effects water points have on rangeland biodiversity. It also identified the large gaps in knowledge surrounding suitable monitoring techniques. We briefly discussed the usefulness of remote sensing and hierarchical modeling which may hold potential for future research.
## 9. Appendix 1

Review of studies conducted into the effects of artificial watering points on rangeland degradation, and fauna and flora composition.

<table>
<thead>
<tr>
<th>Resource</th>
<th>Study conducted</th>
<th>Major findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bastin and James 2002</td>
<td>This case study covers 16 pastoral leases between the Tropic of Capricorn and the South Australian border. Land assessment was based on Landsat MSS and spans 2 periods of major vegetation growth at the regional scale through the 1980s. The PD54 index was used to calculate multitemporal cover. This index is derived from radiance properties of soil and vegetation. Grazing gradient analysis and % of Cover Production Loss was used to determine the extent of land degradation. Indices used were the contagion index, interspersion index and the inflexion point. Most pastorally useful land systems are within grazing range of water, while significant areas of country with low pastoral value are protected by distance from water. A very small proportion of total area of vegetation types with high pastoral productivity is non-degraded. More of the highly productive country is close to water and is more intensively grazed. Non-degraded areas are more homogeneous as they contain a higher proportion of pastorally less productive land systems. Land degradation separates patches and reduces the amount of intermixing with patches of other systems.</td>
<td>Land degradation: Most pastorally useful land systems are within grazing range of water, while significant areas of country with low pastoral value are protected by distance from water. A very small proportion of total area of vegetation types with high pastoral productivity is non-degraded. More of the highly productive country is close to water and is more intensively grazed. Non-degraded areas are more homogeneous as they contain a higher proportion of pastorally less productive land systems. Land degradation separates patches and reduces the amount of intermixing with patches of other systems.</td>
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<tr>
<td>Foran 1980</td>
<td>The effect of distance from water points on rangeland condition was examined for 2 rangeland types in central Australia. These were open woodland communities and mulga annual communities. Rangeland condition was assessed with STARC method which compares species composition to that of a benchmark relict site. A significant decrease in condition with distance from water was observed for both rangeland types. The pisosphere effect can be attributable to many factors other than grazing and stocking intensity, e.g. wind direction, shade availability, type of rangeland, palatability, climatic effects, distance, shape of water point, etc.</td>
<td>Flora: Most pastorally productive systems (open woodland plains, alluvial fans and plains and floodouts) have the highest % CPL and are the most degraded in terms of lack of vegetation recovery following rainfall. Pastorally less productive mulga shrublands, hills, foothills and salt lakes, show complete vegetation recovery following rainfall. Systems containing a higher proportion of palatable forage have higher index values and are most adversely affected by grazing. A higher contagion index in non-degraded areas suggests less patchiness and less intermixing. Interspersion values are lower for non-degraded areas of all vegetation types. This indicates reduced intermixing of patches. The grazing gradient measures an increase in vegetation cover with increased distance from water. Grazing intolerant species are usually water remote, 5-10% of the biota are grazing intolerant of even light grazing. Most vegetation types have less than 10% of total area beyond 10km from water point. Grazing distribution is uneven in both time and space. Most changes in vegetation composition took place within 2 km of the water source. Grazing of pastures is seldom uniform and varies with pasture type, distance and direction from water point. Hodder and Low (1978) found that cattle will graze up to 3–4 km in low to moderate forage conditions. If grazing was uniform we would see zones of different vegetation types form annuli around the waters, but this is not the case.</td>
</tr>
</tbody>
</table>
### Major findings

#### Land degradation

The effects of grazing pressure starts to diminish 1000m from water. The research into long-term use of livestock around the pisosphere is lacking. The breed of cattle may be important.

#### Flora

The data collected show that long-term concentration of cattle causes a decline in perennial grasses with a decrease in distance from water. Weeds and annual forbs dominate the zone under 500m from water. Martin and Ward (1970) found that regulating access to water points could be effective in increasing perennial grass production, compared with that of continuous grazing. Rotating access to water points doubled the yield of perennial grasses over an 8 year period. Most improvement occurred within 300m of water.

#### Fauna

With the absence of surface water, cattle graze closer to water. They move out as feed conditions deteriorate. In good conditions, cattle display a marked preference for riparian communities.

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<thead>
<tr>
<th>Resource</th>
<th>Study conducted</th>
<th>Major findings</th>
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<tbody>
<tr>
<td>Fusco et al. 1995.</td>
<td>The long term influences of livestock grazing were studied on 2 upland Chihuahuan desert ranges in New Mexico. One range was conservatively stocked, while the other was stocked more heavily. Linear Regression Analysis was used to evaluate standing crop data pooled across years.</td>
<td>The effects of grazing pressure starts to diminish 1000m from water. The research into long-term use of livestock around the pisosphere is lacking. The breed of cattle may be important.</td>
</tr>
<tr>
<td>Hodder and Low 1978</td>
<td>Cattle were observed over a period of 5 years on 3 sites near Alice Springs, to determine how different plant communities are utilised.</td>
<td>The maximum distance cattle were observed from water during dry conditions was 13km. The distance cattle graze out from water related to the quality and the quantity of food. Cattle were rarely seen beyond 8 km from water. This dependence on water restricts the forage area. Extreme drought conditions see movement of up to 20km. Cattle appear faithful to a particular watering point, only abandoning it when other temporary surface water is available.</td>
</tr>
<tr>
<td>Landsberg and Stol 1996</td>
<td>The densities and distribution of sheep, kangaroos and feral goats were assessed from extensive dung surveys following dry, moderate and green seasons in three large paddocks in the wooded rangelands of north-western NSW.</td>
<td>Grazing by kangaroos impedes regeneration after the removal of livestock. The total grazing pressure depends not only on density, but on how grazing activities are distributed amongst different vegetation types. Kangaroos showed strong selectivity for vegetation types and very little overlap with goats and sheep. They were much more selective about the environment in which they graze.</td>
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Desert Knowledge CRC

The impact of artificial watering points on rangeland biodiversity: A review
<table>
<thead>
<tr>
<th>Resource</th>
<th>Study conducted</th>
<th>Major findings</th>
</tr>
</thead>
</table>
| Landsberg et al. 2003 | Study measured the frequency of occurrence of all plant species at sites along water centred grazing gradients in central and southern Australia. Four gradients were measured in chenopod shrubland and acacia woodlands. | Land degradation
Bare ground and grass cover were significantly affected by distance to water. Bare ground and grass cover decreased with distance. Forb cover showed little variation between biome or distance zone. |
| Low et al. 1980 | Distribution of cattle grazing the rangeland communities in central Australia was determined from aerial surveys at fortnightly intervals over a 4.5 year period. Changes in grazing intensity, as indicated by density of cattle, were examined under different forage conditions. | Flora
Some species are advantaged by moderate levels of disturbance, while others hold no tolerance. Native species display more of a decline and are restricted to more water remote locations. The decreaser species outnumber the increaser species. For neutral species, this may represent environmental differences. There was a large degree of spatial variation in plant species composition. Singleton species occur further away from water. Few areas remain far enough away from water to support sensitive biota. Such areas are valuable areas of plant diversity. |
| Ludwig et al. 1999 | This study quantifies the density, cover and obstruction width of vegetation patches, the roughness of landscape surfaces and the diversities of plants and grasshoppers with distance from cattle watering points. Distance from water was used as a surrogate for a gradient in grazing pressure. Fourteen study sites were located in the Victoria River District of northern Australia. | Fauna
Unequal distribution of cattle and grazing intensity has been recognised as a dominant problem since 1920 (Low 1972). It is necessary to understand grazing communities and intensities to interpret changes in rangeland condition. |

A rough surface tends to slow water run-off and increase the time for water infiltration and soil water storage. Surface roughness declines near water. Overgrazing can cause a loss of landscape patches and excessive soil erosion. In arid and semi-arid environments, livestock concentrate around water sources, and then radiate out to feed. A decrease occurs in the soil crusts within these regions. Density of dung and hoof prints are highest in sacrifice zones. |

A decrease in palatable plants was observed close to water. Declines were observed just 200m from water. Grazing gradient responses for landscape patches do occur with unpalatable forbs and grasses increasing near water. Diversity of both plant and grasshopper species declined near water and increased further away, before levelling off. |

Grasshopper richness and density declined with the decline in vegetation closer to water. These declines suggest strong linkages between landscape plant function, biodiversity and impacts of cattle grazing and trampling. Few studies on distance from water have looked at the effects on biodiversity. |
<table>
<thead>
<tr>
<th>Resource</th>
<th>Study conducted</th>
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<tbody>
<tr>
<td>Ludwig et al. 2004</td>
<td>Examples taken from published literature document that at finer patch and hill-slopes scales several indicators of landscape functional integrity have been identified, each related to biodiversity.</td>
</tr>
<tr>
<td>Pickup et al. 1998</td>
<td>This paper shows how trends in rangeland conditions can be identified from changes over time in the pattern of vegetation growth across grazing gradients of differing intensity. Grazing intensity was measured using distance from water, and vegetation growth was derived from remotely sensed vegetation index values before and after large rainfalls. A vegetation response was derived by comparing areas less than 4km away from water with benchmark areas further away. The vegetation index PD54 derived from Landsat MSS data was used to measure cover.</td>
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<tr>
<th>Major findings</th>
<th>Land degradation</th>
<th>Flora</th>
<th>Fauna</th>
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<tr>
<td>Functional integrity is the intactness of soil and native vegetation and the processes that maintain these. Functional integrity patterns have been modified through grazing, clearing and fire. Grazed areas display a rapid decline in functionality for surface stability, infiltration and nutrient cycling. Functional integrity varies with soil type, grazing and distance to water.</td>
<td>Plant richness and grasshopper density was lower near water points. The increases in species near water are shorter lived herbs. Native species display more of a decline with grazing pressure. Understorey plants and birds are more accurate indicators of grazing intensity.</td>
<td>Biodiversity should be strongly related to integrity.</td>
<td></td>
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Desert Knowledge CRC

The impact of artificial watering points on rangeland biodiversity: A review

Major findings

<table>
<thead>
<tr>
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<tr>
<td>Pringle and Landsberg 2004</td>
<td>Using research results from the Goldfields of Western Australia, distance from water was incorporated into models of grazing history at different sites within the paddock.</td>
</tr>
<tr>
<td>Read 1999</td>
<td>The effect of 2 pulses of heavy cattle grazing on chenopod shrubland plants and invertebrates was assessed over a 2-year trial in South Australia. Study location consisted of sand dunes vegetated with large shrubs and small trees. Stock grazing had been absent before study. Both plant and invertebrate communities were structured by sub-habitats defined by edaphic and water distribution features. Dung counts were used to measure relative grazing pressure.</td>
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Land degradation

Stock track densities declined with distance from water sources and are used to estimate grazing pressure. This may also reflect past pastoral activity as it is difficult to determine recent behaviour. Areas of high track density reflect past heavy usage; it reflects a longer time frame and is easier to sample. Track density declines rapidly with distance from water. The livestock paths may intensify the natural drainage patterns and exacerbate the erosion process. Water use depends on the animal, age, sex, water salinity, temperatures, size and shape of paddock, availability of natural water sources, etc.

Flora

Heavily grazed areas are desirable habitat for the spread of exotic species. Fire appears to improve pastures, but grazing needs to be controlled. Competition between livestock and macropods occurs around preferred pastures and water points. Macropods are not contained by fences. The loss of natural water sources encourages the concentration of fauna around permanent water sources. Rabbits do not depend on water but do severely affect the vegetation. Feral animals are attracted to the region, yet all use the landscape differently.

Fauna

There appears to be no universal response in biodiversity to the impact of grazing. A regional approach is needed. Drainage features (billabongs, clay pans, duricrusts, etc) often support the most biodiversity. Nature and distribution of feral animals vary between species and regions. Goats rely on water, but use the country differently to sheep and cattle. Rooting activities by pigs cause damage to the water source.

Soil surface on the dunes and run-on areas were severely disturbed, but microbiotic crusts remained largely intact.

The cover of most common plant species changed following grazing. *Atriplex vesicaria* and *Maireana astrotricha* (two of the most dominate vegetation species) declined significantly following grazing. The cover of shorter-lived unpalatable chenopods generally increased at grazed sites. A number of plant species increased in the grazed areas, particularly following good rains. These included a number of unpalatable species.

Cattle, rabbit and particularly kangaroo dung were most abundant at run-on sites and least abundant at run-off sites. Dune base sites typically supported a higher abundance of invertebrates. Run-off sites were generally impoverished in invertebrates in comparison with run-on sites.
10. References


McGarigal K and Marks BJ 1995, FRAGSTATS: spatial pattern analysis program for quantifying landscape structure, Oregon State University, Oregon.

Mifsud G 1999, ‘Ecology of the Julia Creek dunnart, Sminthopsis douglasi, (Marsupialia: Dasyuridae)’, Masters Thesis. La Trobe University, Bundoora.


Smyth A 2003, Key conceptual, biophysical and statistical issues for designing biodiversity monitoring framework for the rangelands, Centre for Arid Zone Research, CSIRO Sustainable Ecosystems, Alice Springs.


