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Alinytjara Wilurara Natural Resources Management Board

Adapting to Climate Change on Country

Climate Change Addendum - Technical Report
for the

Alinytjara Wilurara Regional Management Plan

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Australian Government

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for the

Alinytjara Wilurara Regional NRM Plan

Australian Government

Stream 1 of the
Regional Natural Resources Management Planning for Climate Change Fund

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For the Alinytjara Wilurara Natural Resources Board Management Board

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Executive Summary

This report examines opportunities for adaptation to climate change risks within the Alinytjara Wilurara (AW) Natural Resource Management (NRM) region. Work undertaken for the AW NRM Board between May 2013 and December 2014 for the Federal Government "Regional NRM Planning for Climate Change Fund" is summarised and key opportunities for adaptation are outlined. It supports the Addendum to the AW Regional NRM Plan with the aim of informing climate change adaptation priority areas across the region. The goal of this report and the related Addendum is to guide spatial adaptation to climate change impacts on natural ecosystems, as well as to examine opportunities for carbon bio-sequestration (carbon farming) activities in the AW NRM region.

What's changed already?

The climate has already changed in Australia over the past century. In the AW NRM region, average temperatures have risen between 0.5°C and 1.5°C since 1910 (BoM and CSIRO 2014) at an average rate of 0.05-0.15°C per decade (Figure 1). The AW NRM region has also experienced a wetting trend in more recent decades, particularly in the north during summer months, possibly as a result of a strengthening summer monsoonal system in northern Australia (BoM and CSIRO 2014) (Figure 2).

Figure 1 Annual mean temperature changes across Australia since 1910. (AW NRM region shown in red outline; source: BoM and CSIRO 2014)

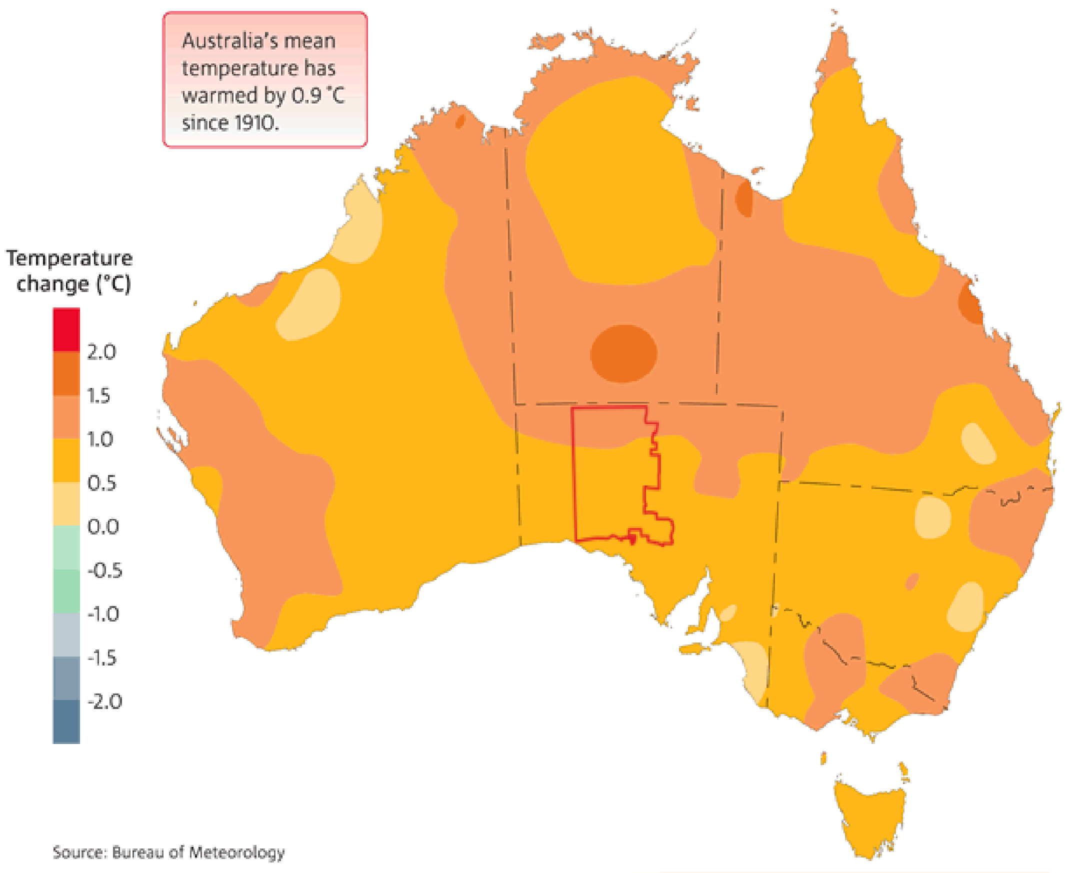
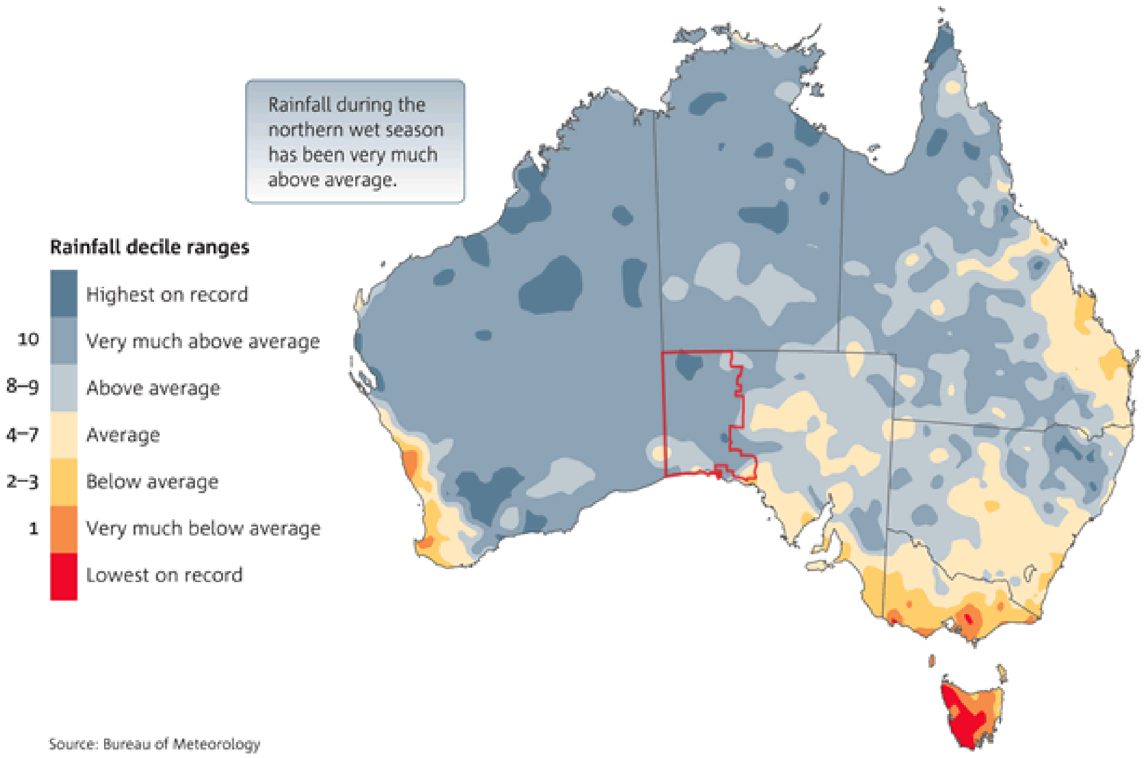


Figure 2 Northern wet season (October–April) rainfall deciles since 1995–96. A decile map shows the extent that rainfall is above average, average or below average for the specified period, in comparison with the entire national rainfall record from 1900. (AW NRM region shown in red outline; source: BoM and CSIRO 2014)



What about the future?

As part of Stream 2 of the Australian Government's *Regional NRM Planning for Climate Change* Fund, CSIRO and BoM have developed new projections for the Australian Rangelands which are divided into two zones (Rangelands North and Rangelands South) spanning the AW NRM region (Figure 3; CSIRO 2014). The best estimates for future climate in the two zones display overall trends (Table 1). Stream 2 also provides detailed descriptions of climate change emissions scenarios, one representing a stabilised climate by 2100 (RCP4.5) and one representing little change in Greenhouse Gas emissions and no climate stabilisation (RCP8.5) for the two zones.

Figure 3   The AW NRM region, Stream 2 Rangelands zones, and seasonal rainfall dominance (red = summer dominant, blue = winter dominant)

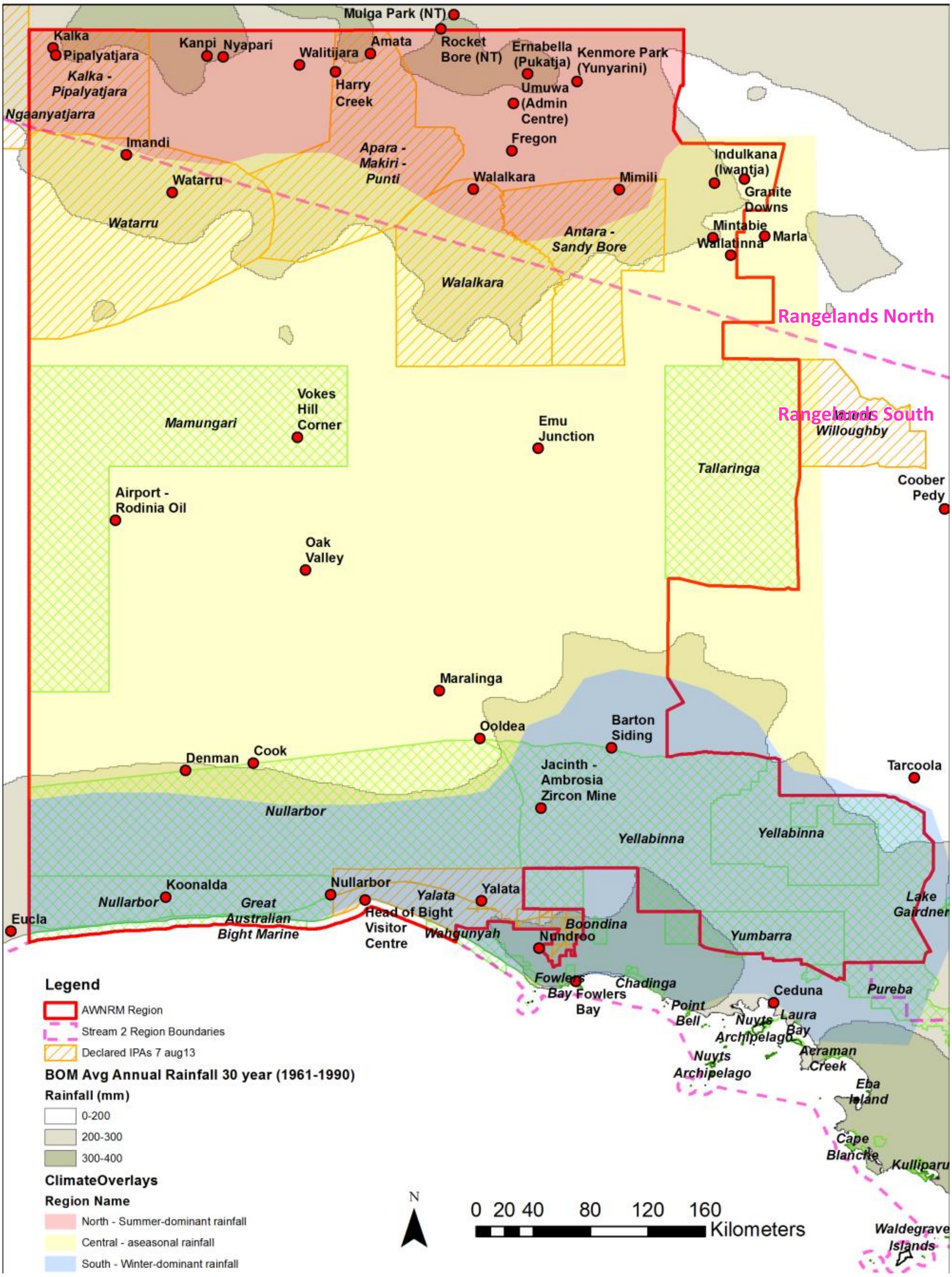


Table 1 Climate projections for North and South Zones developed from Stream 2 work (CSIRO 2014)

	Overall trend	Scenario	Variable	2030	2090
North	Hotter, possibly more regular large downpours in summer, but generally drier	Late century emissions stabilisation (RCP4.5)	*Temperature:*	Warmer	Hotter
			Rainfall:	Little change to drier	Drier (but with some uncertainty)
		High emissions (RCP8.5)	*Temperature:*	Warmer	Much hotter
			Rainfall:	Little change to wetter (but with large uncertainty)	Drier (but with large uncertainty)
South	Hotter, drier, rising sea levels along coast	Late century emissions stabilisation (RCP4.5)	*Temperature:*	Warmer	Hotter
			Rainfall:	Little change to drier	Drier (but with some uncertainty)
		High emissions (RCP8.5)	*Temperature:*	Warmer	Much hotter
			Rainfall:	Little change	Little change to much drier (but with large uncertainty)

Definitions

Temperature (annual average): Warmer: 0.5-1.5°C; Hotter: 1.5-3°C; Much hotter: > 3°C
Rainfall (annual average): Little change: -5 to 5%; drier: -15 to -5%; wetter: +5 to 15%; much drier, < -15%

While there is little doubt that there is likely to be an ongoing warming trend for the AW NRM region, rainfall projections from the CSIRO (Table 1) suggest that a drying trend is also likely for the region. Future rainfall trends are however, highly uncertain, particularly as average rainfall has been increasing across the region in recent decades (Figure 2).

How can the AW NRM region prepare?

The changes to climate will have significant impacts on ecosystems and communities within the AW NRM region. Given the large spatial extent of the region and lack of scientific baseline data, community knowledge on local current and future impacts is highly important. To accompany scientific projections therefore, local Anangu perceptions of climatic impacts and change were sought during workshops in 2011 and 2014 to inform priorities for future management and adaptation in the region. Mapping activities were conducted with some AW NRM communities to determine where problem areas existed and where important responses were required. The maps are used within this technical report, in conjunction with other spatial data sets (e.g. water assets, vegetation cover and fire scars), and research products from Stream 2, to establish short- and long-term adaptation priorities across the AW NRM region. Future work by AW will incorporate these opinions and concerns into climate change planning in all communities as part of the integrated healthy country planning program.

Priority adaptation projects in the region include:

In the North:

- **Protection of long-lived carbon assets** in major drainage channels in APY (primarily headwaters and lower reaches of Officer Creek catchment, but also around Kanpi-Nyapari)
- **Designation of bushfood zones** in areas of high hunting, invasive species, fire or community pressures to reduce non-climatic pressures on native species within vital ecosystems
- **Integrated management of fire and Buffel grass along roads** as these represent the key areas of ignition and also the major sources of Buffel grass seed spread
- **Adaptation to heatwaves,** for communities, stock and native species, particularly to ensure vulnerable community members are cared for
- **Managing flooding** by reducing risks to key infrastructure, and providing community reserves of fuel, food, and medicine
- **Developing seasonal calendars** as monitoring tools to track changes in flowering, breeding and other phenomena over time

In the South:

- **Protection of long-lived carbon assets** in the southern third of Mamungari Conservation Park (CP) and north of the Nullarbor Plain
- **Managing southward migration of Buffel grass** by concentrating control along major road and rail lines and in Yalata community
- **Reducing the risks of sea level rise** by relocating camp sites higher and further away from the shoreline
- **Adaptation to heatwaves,** for communities and native species, particularly to ensure vulnerable community members are cared for
- **Developing seasonal calendars** as monitoring tools to track changes in flowering, breeding and other phenomena over time

A full list of current stakeholder issues, future climate change impacts, and adaptation responses within each theme are summarised in Tables 2 and 3, and are sorted into themes that arose during conversations with communities. The distinction is made between short-term adaptation activities to reduce specific vulnerabilities, and long-term actions to increase resilience.

Nathanael Wiseman consulting with Anangu elders at Nyapari

Where relevant, adaptation responses are followed by bracketed notes, e.g. '(W1)' to indicate that they are supported by existing actions in current Alinytjara Wilurara Regional NRM Plan, using the numbering convention outlined in Section 2. Where no bracketed note exists, it indicates a new action not currently supported in the existing Alinytjara Wilurara Regional NRM Plan. The maps that follow the tables (Figures 4 and 5) indicate large-scale adaptation responses at a sub-regional to regional scale – for finer-scaled responses, please refer to Section 4 of this report.

Table 2   Summary of themes and adaptation responses in the North

	Buffel grass	**Fire management**	**Heatwaves**	**Bushfoods**	**Water management**	**Livestock grazing**	**Feral animals**	**Biodiversity and Carbon**
Current State	Buffel grass is widespread and negatively impacting on important bushfoods and biodiversity	Fire regimes have changed dramatically since European colonisation, due to less traditional burning and introduction of Buffel grass Fire presents a significant risk to communities and infrastructure in the APY Lands given the current lack of response capacity	Heatwaves are impacting on communities, particularly the elderly or sick who cannot easily leave the lands during the hotter months Blackouts are common under peak loads from air conditioning Recent heatwaves have negatively impacted on biodiversity	Bushfoods are declining due to a combination of Buffel grass invasion, over-hunting, feral animal competition and predation, and cattle grazing	Groundwater levels are already declining in some communities and pastoral stations due to over-extraction Rockholes are being over-exploited and damaged by feral camels. Flooding has impacted on communities, damaging infrastructure and cutting off roads and access to food. People staying in homelands get cut off for weeks	Grazing is destroying bushfoods in some areas, as well as biodiversity Stock waters are drying up due to over-extraction	Feral animals, including camels, donkeys, horses, red foxes, rabbits and cats are causing significant environmental damage, including damage to bushfoods and sacred sites such as rockholes	Long-term decline in woody biomass (e.g. mulga woodlands) has been observed in parts of the AW NRM region due to changing fire regimes and introduction of feral herbivores Carbon planting is marginal in most of the region due to low rainfall, and frequent fire regimes which prevent long-term carbon accumulation
Future Issues with Climate Change	Buffel is unlikely to be controlled over large areas due to the high likelihood of reinvasion and suitability to a warmer, higher CO_2 climate	Fire risk is likely to increase in a changing climate, due to a combination of hotter temperatures which extend the fire season and increase the number of extreme fire weather days, larger summer rains which will increase the amount of biomass and hence fuel loads, and the predicted spread of Buffel grass. The window for prescribed burning is likely to shorten	Heatwaves are likely to get hotter, longer and more frequent	The existing drivers of bushfood decline are likely to intensify with future climate change, as well as increases in heatwaves and more variable rainfall Climate change will change the timing of important seasonal events such as hibernation and flowering/fruiting	Larger downpours may increase aquifer recharge in the central ranges, but increasing temperatures will put increase pressure on groundwater extraction to supply communities and stock, and for emergency fire management Heavier rains will likely increase flood impacts	Increasing temperatures and heatwaves and more variable rainfall will put increased pressure on stock and supporting resources (water, feed, grazing land)	Large feral herbivores (camels, donkeys, and horses) as well as the red fox present the biggest threats as a result of climate change, with these species projected to either remain stable (feral herbivores) or increase in abundance (red fox). In contrast, rabbits, cats and goats are projected to decrease either in abundance or distribution	The drivers of woodland decline are likely to intensify with climate change. CFI activities present significant risks due to increased fire intensity and decreases in natural carbon sequestration rates due to hotter temperatures and increased fire frequencies

	Buffel grass	Fire management	Heatwaves	Bushfoods	Water management	Livestock grazing	Feral animals	Biodiversity and Carbon
Short-term adaptation priorities (bracketed notes, e.g. 'W1' indicate support of existing actions in current AW Regional NRM Plan)	Roadside control of Buffel grass (C4) Prioritise control within major drainage lines and creeklines, working from upstream down (see Carbon and Biodiversity) Asset protection (built and natural assets) by prescribed burning, herbicide application, grading, or controlled grazing Monitor Buffel grass in the southern parts of Walalkara, Antara-Sandy Bore and Watarru IPAs	Concentrate fire management along major roads, as these are the highest sources of ignition (C10) Increase prescribed burning around woodland vegetation (e.g. Desert Oaks between Amata and Kanpi, mulga woodlands in Watarru IPA, and along major drainage lines) (C10)	Have a record to check of vulnerable people in community Ensure access to air-conditioning and swimming pools during summer months Manage peak loads with spare generators or solar PV to prevent blackouts Ensure stock and mustered animals have access to adequate shade and water Provide alternative water points for native animals	Conduct patch burning to reinstate traditional fire seral mosaics, and monitor post-fire recovery of plants and animals (C10, C12) Manage feral animals to reduce competition and predation (C3)	Implement groundwater resource monitoring and develop alternative supplies for high risk communities, which include Amata, Ernabella, Kenmore Park and Fregon (W11, W15) Ensure rockholes are cleaned regularly to store maximum water Ensure timely maintenance of stock waters to prevent stock dehydration and stress Conduct audit of significant rockholes and other aquatic refuges using Davis' (2014) methodology, combined with cultural significance weighting, to determine a management priority list of surface water resources and groundwater dependant ecosystems, such as the major creeklines (C9, W3, W7, W21)	Conduct regular community-based monitoring of existing grazing photopoints (C2) Set and enforce stocking rates based on existing pasture coverage and quality Ensure shaded areas are available for stock to rest during heat waves to reduce stress Shade stock waters to reduce evaporation rates Limit stock access to creeklines to reduce damage to long-lived carbon assets	Construct mustering yards for feral herbivores in line with Feral Animal Management infrastructure plan (AW NRM 2014) (C3) Ensure adequate shade and water is available to prevent heat-related stress on mustered stock. Minimise stock holding times before they are removed to reduce heat-related stress Provide payments for feral animal culling and monitoring	Prioritise management of major drainage lines (e.g. Officer Creek) – and control livestock/feral herbivore pressure and Buffel grass within and adjacent to these areas

	Buffel grass	Fire management	Heatwaves	Bushfoods	Water management	Livestock grazing	Feral animals	Biodiversity and Carbon
Longer-term resilience actions	Develop biocontrol measures Develop a use for harvested Buffel grass – e.g. as fuel, fodder, biochar feedstock, etc. Support community monitoring and management of outbreaks	Develop community CFS programs which involve interested community members in fire management and training for both traditional cultural reasons and also asset protection activities. This could be developed through TAFE as an accredited training program (P11) Develop fire fund which is tied to seasonal rainfall to provide adequate funding for prescribed burning following wet years when the need is greater. Deposits can be made every year, with withdrawals made only after exceptionally wet periods Consolidate fire management activities as the fire season extends – perhaps using casual staff or other flexible arrangements to focus activity in the brief window of opportunity before the fire season begins	Improve building thermal performance, increase shade trees, improve community health Consider temporary migration for vulnerable people within communities during the summer months Schedule the majority of NRM work during the cooler months of the year Consider assisted migration of sensitive species (e.g. Warru) to higher, cooler refuge areas	Designate refuge areas where bushfoods are more intensively managed through conservation works and controls on hunting, to provide surrounding areas with greater hunting opportunities These conservation zones could also be managed for carbon assets where appropriate to achieve multiple benefits to communities Implement community-based monitoring of hunting and harvesting to better understand bushfoods that are under threat from over-harvesting Implement community-based monitoring of seasonal events to track changes in bushfoods over time (C26, C27, P7, P10, P13, P19)	Implement groundwater resource monitoring for all major communities in the region (W15) Implement water conservation measures in communities, including transparent information on household water use, and investigate pricing mechanisms to regulate overuse (W16) Utilise rainwater harvesting techniques to passively irrigate community trees and reduce peak stormwater flows and flood risk Development supplemental supply, with larger rainwater tanks sized for projected increases in peak rainfall intensity Investigate ways of augmenting inflows into rockholes through swales, and reducing outflows by fencing feral animals out and shading rockholes with vegetation or shade cloth Ensure essential community infrastructure is located away from flood-prone areas	Monitor long-term seasonal forecasts Stock for the worst years, not the best to conserve perennial vegetation, or ensure rapid changes to stocking rates with seasonal changes Create ponding banks where there is erosion potential to capture larger rainfall events, reduce erosion and grow productive perennial grasses Use smaller paddocks, more water points and higher rotations with long rest periods Breed cattle as part of operations and select for resilient stock	Encourage dingo populations in order to increase predation of and competition with the red fox, which is the only species projected to increase in abundance with future climate change. Aerial culling of camels may support larger dingo populations by allowing them to feed on the carcasses Develop local abattoir processing capability and infrastructure for mustered feral herbivores to reduce heat stress on animals, provide local employment, and provide a buffer against heatwaves (e.g. cold storage) or floods preventing truck access and decline in animal condition	Manage threatening process (particularly inappropriate fire regimes and feral herbivores – C3, C10) to promote natural carbon regeneration, rather than planting trees Ensure riparian vegetation (predominantly *Eucalyptus camaldulensis*) is regenerating naturally through ongoing monitoring

Figure 4 Subregional-scale summary of adaptation responses in the North (finer-scaled adaptation responses omitted from this figure)

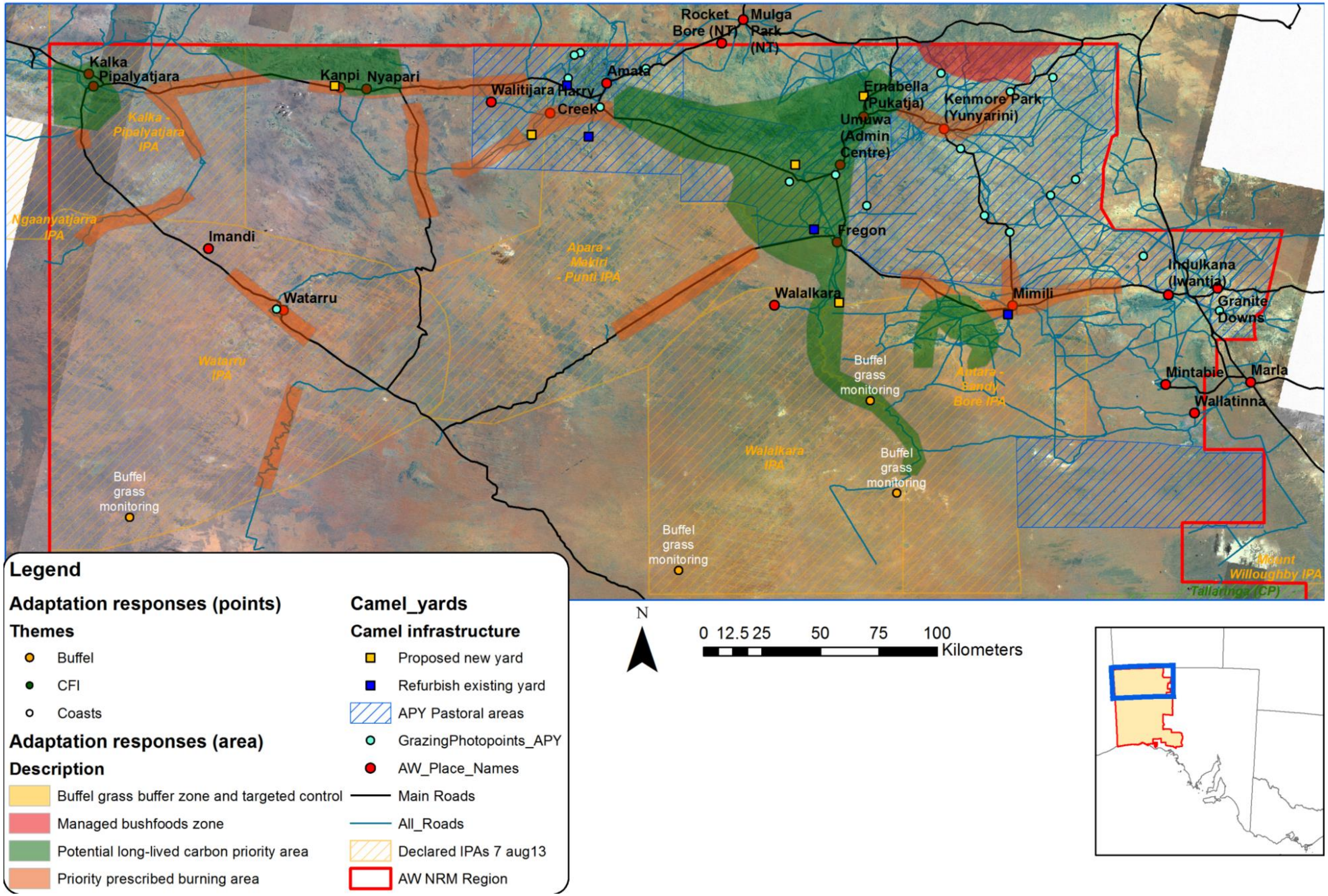


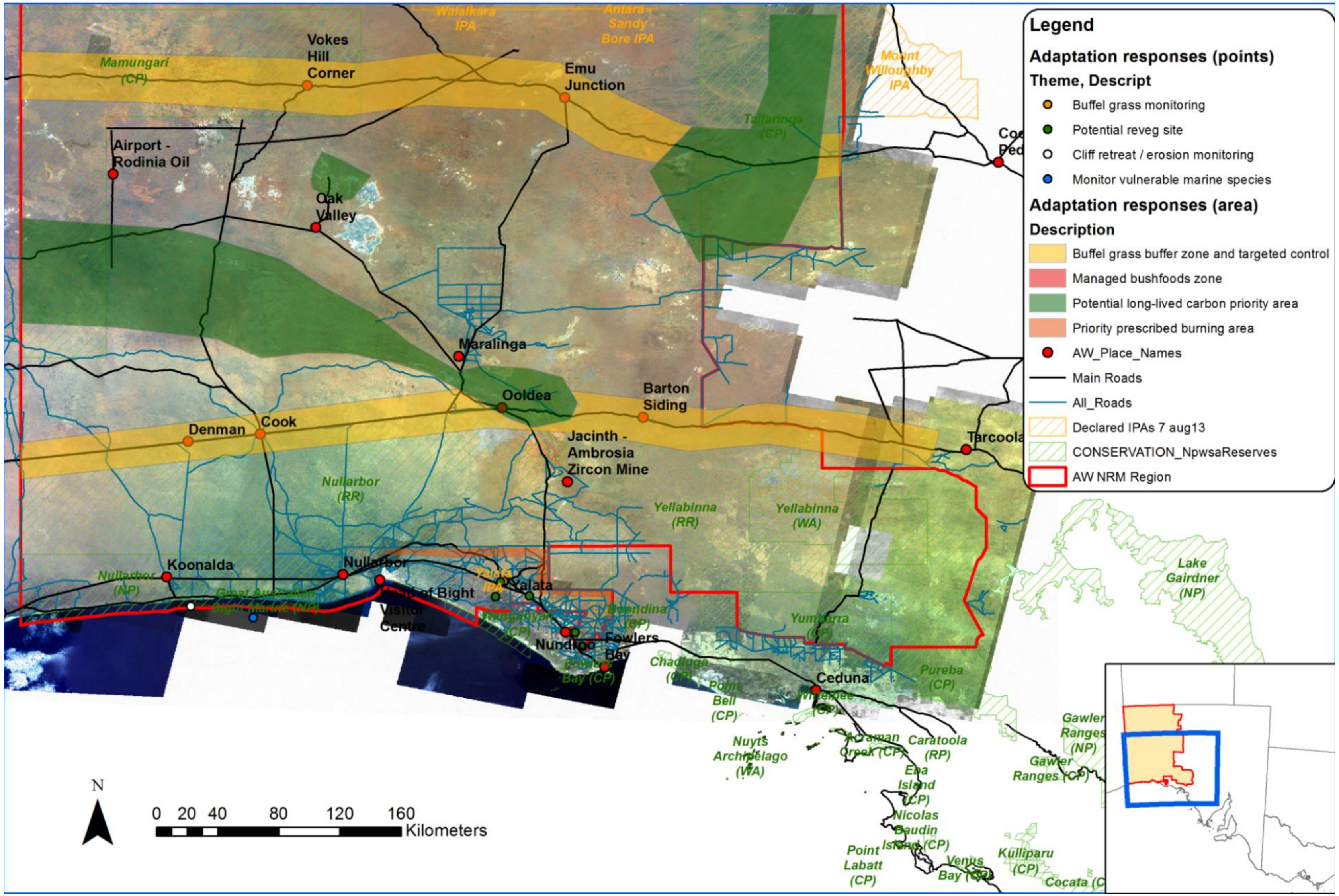
Table 3 Summary of themes and adaptation responses in the South

	Buffel grass	**Fire management**	**Heatwaves**	**Bushfoods**	**Water management**	**Feral animals**	**Coastal zone**	**Biodiversity and Carbon**
Current State	Buffel grass has been observed in Yalata Community, as well as along roads and the rail line	Fire regimes have changed since European colonisation. Fire presents a significant risk to IPA management given the lack of response capacity	Heatwaves are impacting on communities, with blackouts common under peak loads in summer from air conditioning Recent heatwaves have negatively impacted on biodiversity	Some bushfoods such as red kangaroo are declining due to a combination of over-hunting and feral animal competition (particularly rabbits and camels). Dingo populations have controlled foxes and cats to some extent Changes were noticed in some fish species, linked to changes in currents and ocean temperature	Groundwater levels in Yalata are declining due to over-use Groundwater in Oak Valley is depleted – water is sometimes brought up from Yalata Insufficient emergency water for tourists and fire-fighting	Camels are less of an issue for Yalata IPA compared with further north Rabbits, cats and foxes all impact on native biodiversity	Storm surges have washed out low-lying campsites in the past Changing ocean currents and temperatures have led to unusual fish and other marine species being identified along the AW coastline	Long-term decline in woody biomass has been observed in parts of the AW NRM region due to changing fire regimes and introduction of feral herbivores Carbon plantings may be viable in the southern edge of Yalata IPA
Future Issues with Climate Change	Buffel grass is likely to spread further south in a warming climate. Containment is essential to prevent further spread which will be impossible to remove if it becomes established	Fire risk is likely to increase in a changing climate, due to a combination of hotter temperatures which extend the fire season and increase the number of extreme fire weather days, and the predicted spread of Buffel grass. The window for prescribed burning is likely to shorten	Heatwaves are likely to get hotter, longer and more frequent	The existing drivers of bushfood decline are likely to intensify with future climate change, as well as increases in heatwaves and more variable rainfall Climate change will change the timing of important seasonal events such as hibernation and flowering/fruiting, and may further change fish patterns due to change in currents and temperature	Oak Valley and Yalata are at low risk of climate change impacting on groundwater levels, but both communities are at risk from over-extraction Hotter temperatures and increased fire risk will increase the need for emergency water supplies, as well as increase the demand for water within communities	Large feral herbivores (camels, donkeys, and horses) as well as the red fox present the biggest threats as a result of climate change, with these species projected to either remain stable (feral herbivores) or increase in abundance (red fox). In contrast, rabbits, cats and goats are projected to decrease either in abundance or distribution	Rising sea levels and associated storm surges will further threaten coastal camps Changing coastal patterns (e.g. wave direction, sea temperature, wind erosion) may change habitat suitability for species	The drivers of woodland decline are likely to intensify with climate change CFI activities present significant risks due to increased fire intensity and decreases in natural carbon sequestration

	Buffel grass	Fire management	Heatwaves	Bushfoods	Water management	Feral animals	Coastal zone	Biodiversity and Carbon
Adaptation priorities (bracketed notes, e.g. 'W1' indicate support of existing actions in current NRM Plan)	Containment and eradication of Buffel around Yalata is a high priority Quarantine measures which prevent cars from spreading seed from further north should be investigated (C2) Support community control along the rail line and major roads to prevent Buffel spreading further south is also a priority (C2)	Increase prescribed burning on northern Yalata IPA boundary to reduce grass fires spreading from further north (C10) Increase the number of shed tanks in the more remote sections of Yalata IPA to improve fire-fighting capacity	Ensure access to air-conditioning and swimming pools during summer months Manage peak loads with spare generators or solar PV	Conduct patch burning to reinstate traditional fire seral mosaics, and monitor post-fire recovery of plants and animals (C10, C12) Manage feral animals to reduce competition and predation (C3)	Establish shed tanks in strategic locations for emergency water supplies for tourists and fire-fighting Implement water conservation measures in communities, including transparent information on household water use, and investigate pricing mechanisms to regulate over-use. (W13, W16)	Continue aerial culling programs for feral camels (C3) Continue baiting programs for foxes, and control for rabbits (C3) Provide payments for feral animal culling and monitoring	Relocate low-lying campsites further away from the shoreline, and provide supplementary water points for emergency use Record species caught by recreational fishers, perhaps by promoting the Redmap software: http://www.redmap.org.au/ (C27, C28) Establish monitoring points to record dune movement over time Track trends in groundwater levels at Yalata Swamp	Investigate carbon potential of groundwater-dependant vegetation to the north of the Nullarbor Plain, and in the southern third of Mamungari Conservation Park

	Buffel grass	Fire management	Heatwaves	Bushfoods	Water management	Feral animals	Coastal zone	Biodiversity and Carbon
Longer-term resilience actions	Develop bio-control measures – this may be particularly applicable in the South where Buffel is not such an important pasture species compared with northern Australia	Greater funding for training and coordinated responses to fire through local CFS teams Concentrate fire management activities and funding to the coolest part of the year to achieve prescribed burning objectives before the fire season	Improve building thermal performance, increase shade trees, improve community health Consider temporary migration for at-risk people within communities during the summer months Schedule the majority of NRM work during the cooler months of the year	Designate refuge areas where bushfoods are more intensively managed through conservation works and controls on hunting, to provide surrounding areas with greater hunting opportunities These conservation zones could also be managed for carbon assets where appropriate to achieve multiple benefits to communities (e.g. to the north of the Nullarbor Plain) Implement community-based monitoring of hunting and harvesting to better understand bushfoods that are under threat from over-harvesting Implement community-based monitoring of seasonal events to track changes in bushfoods, whales and fish over time (C26, C27, P7, P10, P13, P19) Encourage dingo populations to increase predation on foxes and cats	Development supplemental supply, with larger rainwater tanks sized for projected increases in peak rainfall intensity and longer dry periods	Encourage dingo populations in order to increase predation of and competition with the red fox, which is the only species projected to increase in abundance with future climate change. Aerial culling of camels may support larger dingo populations by allowing them to feed on the carcasses	Provide space for swamp ecosystems to retreat in-land and allow for natural colonisation by salt-marsh species in response to rising water levels Determine and monitor cliff retreat rates and plan access roads and other infrastructure to minimise impacts of cliff retreat	Manage existing long-lived carbon assets by controlling threatening process (particularly inappropriate fire regimes and feral herbivores) to promote natural carbon regeneration, rather than planting trees which carries greater risks

Figure 5 Subregional-scale summary of adaptation responses in the South (finer-scaled adaptation responses omitted from this figure)



1. Introduction

This report supports the addendum to the Alinytjara Wilu̲rara (AW) Regional Natural Resource Management (NRM) Plan with the aim of informing climate change adaptation across the region (AW NRM Board 2011). It was developed as part of an Australian Government initiative (*Stream 1—Regional NRM Planning for Climate Change Fund),* which aims to help regional NRM organisations incorporate climate change adaptation and mitigation measures into their existing regional NRM plans. The goal is to guide the management of climate change impacts on natural ecosystems, as well as to examine opportunities for carbon sequestration activities in the AW NRM region. It builds on previous work conducted by the authors on climate change vulnerability (Bardsley and Wiseman 2012a) and community-based monitoring (Wiseman and Bardsley 2013a) in the region over the past four years.

Climate change will impact on the natural resources of the AW NRM region in complex ways. While there is strong agreement that temperatures will continue to rise over the 21st century, the projections for rainfall, particularly in the north of the region, are highly uncertain (CSIRO 2014). This presents a challenge for management and planning, given that rain is largely what drives the ecosystems of this semi-arid region. Furthermore, changes in temperature and rainfall will have interactive and compounding effects on water, fire, grazing, biodiversity, feral animals and other sub-systems of the region, making predictions and preparations appear almost impossible. However, there are activities that can be conducted within each of these sub-systems which improve resilience and reduce vulnerability to both current threats and future change, regardless of what the future holds. In addition, community-based monitoring can play a significant role in observing ecosystem trends and preparing communities for future change, at the same time as acting as an engagement tool for communities to begin to integrate climate change thinking in all programs.

A strong stakeholder focus was taken in this project to determine the spatial requirements for climate change adaptation in and around communities. For that reason, the proposed activities represent community and other regional stakeholder views more closely than, for example, activities ranked purely on the basis of their ecological significance or carbon mitigation potential. This bias reflects a number of realities in the AW NRM region, including a general lack of consistently available scientific ecological data, and the observation that unless there is broad community support for adaptation and mitigation activities, such activities are unlikely to be implemented in the region. In addition, the potential for commercial carbon sequestration is likely to be problematical due to the combination of a semi-arid climate leading to low biomass accumulation rates, and regular wildfires, which make any long-term carbon sequestration commitments a risky venture. Finally, the large and sparsely populated region necessitates a community-focussed approach in setting adaptation priorities because there are substantial difficulties and costs involved in accessing more remote areas. For all of these reasons, this report focuses on activities that can support communities to develop general resilience in local socio-ecological systems in response to future climate change impacts, as well as to the multitude of existing challenges facing the region.

This report is structured as follows:

- Section 2 summarises previous work on climate change in the AW NRM region and conducts a gap analysis of the existing NRM Plan;
- Section 3 outlines climatic features of the region, including observed climatic changes to date, and then discusses future projections based on the latest Commonwealth Scientific and Industrial Research Organisation (CSIRO) modelling;
- Section 4 discusses stakeholder responses across a number of NRM sectors, and outlines likely climate impacts on these sectors, as well as adaptation and mitigation priorities at both sub-regional and local scales;
- Section 5 discusses additional monitoring opportunities; and,
- Section 6 outlines key knowledge gaps and recommendations for future research; and is then followed by a conclusion.

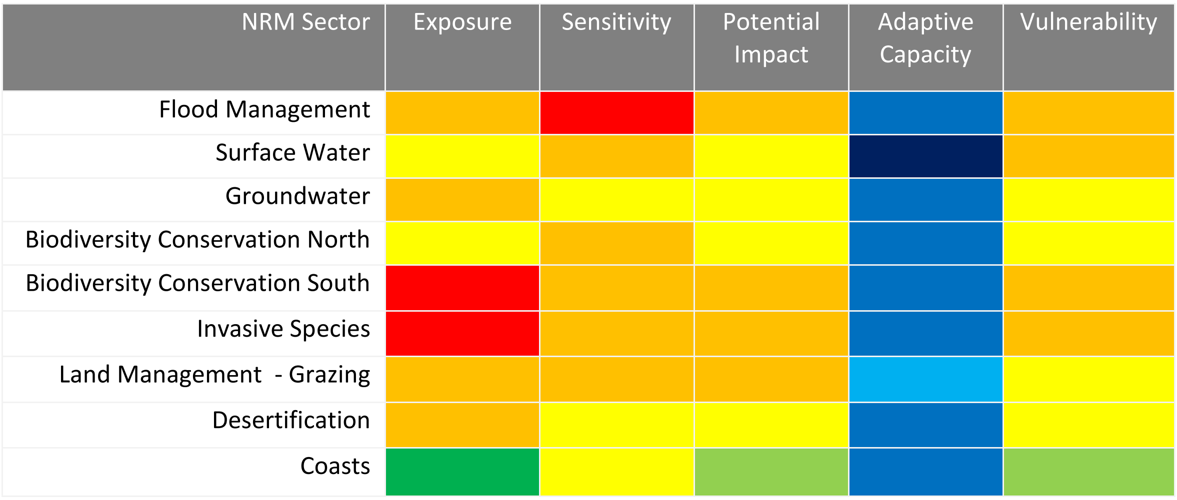
2. Summary of previous work and gap analysis

2.1 Summary of previous work

This work builds on several past projects conducted for the AW NRM Board on climate change. These projects include an integrated climate change vulnerability assessment for the region (Bardsley and Wiseman 2012a), and a review of opportunities for community monitoring of environmental change in the region, including an analysis of other national and international examples of best-practice indigenous community-based monitoring approaches (Wiseman and Bardsley 2013a). Several peer-reviewed papers (Bardsley and Wiseman 2012b, Wiseman and Bardsley 2013b) have also been published as a result of this work. A summary of the projected vulnerability of different NRM sectors to climate change in the AW NRM region was generated as part of the earlier research (Table 4), as were recommendations for regional adaptation planning.

While none of the AW NRM sectors were judged to be highly vulnerable to climate change to 2030, it is the combination of declining natural resources as a result of invasive species, changed fire regimes, changing relationships between people and country, and climate change which forms the biggest risk to socio-ecological systems in the region (Bardsley and Wiseman 2012). Strong arguments have been made for a holistic approach to climate change adaptation and mitigation which aims to increase general resilience to both current and future challenges, rather than piece-meal efforts which only address single issues in isolation (Bardsley and Wiseman 2012a,b). Integrating community-based monitoring as a key component of learning about and responding to risk and environmental change is also necessary, in ways which reinforce and support traditional indigenous culture and knowledge at the same time as shedding new light on contemporary NRM issues (Wiseman and Bardsley 2013a,b).

Table 4   Summary of climate change vulnerability analyses for natural resource management in the Alinytjara Wilurara Region (Bardsley and Wiseman 2012a)



Colour Key for Exposure, Sensitivity, Potential Impact and Vulnerability (not adaptive capacity)

High   Medium-High   Medium   Low-medium   Low

Colour Key for Adaptive capacity

Limited   Medium   Significant

Whereas the initial integrated vulnerability assessment and monitoring review for the region were focussed at a high-level regional scale, the recent work with AW communities and NRM stakeholders has identified, at local to sub-regional scales, important climate change adaptation priorities and monitoring opportunities to spatially inform management planning.

2.2 Gap analysis of existing NRM plan

A review was conducted of the existing AW Regional NRM Plan (2011) in relation to climate change targets and objectives. The strategic goals in this NRM Plan which specifically mention climate change are identified in Table 5. This NRM Plan prioritises goals with outcomes for people, country and water, so the elements of these goals are briefly analysed for their current relevance for climate change adaptation.

Table 5 Existing strategies which specifically mention climate change in the AW Regional NRM Plan (adapted from AW NRM 2011)

	People	**Country**	**Water**
Long-term outcomes	None	**Management under changing climate** There is improved management of water, land and sea under a changing climate	**Healthy water** Healthy ground and surface waters are managed within ecologically sustainable limits, while considering climate change
Intermediate outcomes	None	There is regular monitoring of key sites and indicators for climate change impacts	Water is allocated to industry using sustainability thresholds and incorporating climate change considerations
Actions	None	• Understand trends in landscape health, climate and environmental changes by implementing monitoring • Identify risks from climate change • Continue to support new and existing research projects, particularly those related to climate and changes induced by climate	• Support research on the impact of climate change on water resources (particularly its impact on recharge) specific to the region • Identify sites to begin monitoring ground water usage impacts on vegetation and changes in groundwater due to climate change
Indicators of success	None	Monitoring established at key sites looking for early indications of climate change impacts	Community planning takes into account water availability, particularly under climate change predictions

There is currently a clear gap in the existing AW Regional NRM Plan in relation to the roles and responsibilities of people in relation to a regional climate change response. As highlighted in the initial review of adaptation options for the AW NRM region (Bardsley and Wiseman 2012a) and subsequent publications (Bardsley and Wiseman 2012b, Wiseman and Bardsley 2013b), people must become the central element of climate change adaptation initiatives in the remote north-west of South Australia.

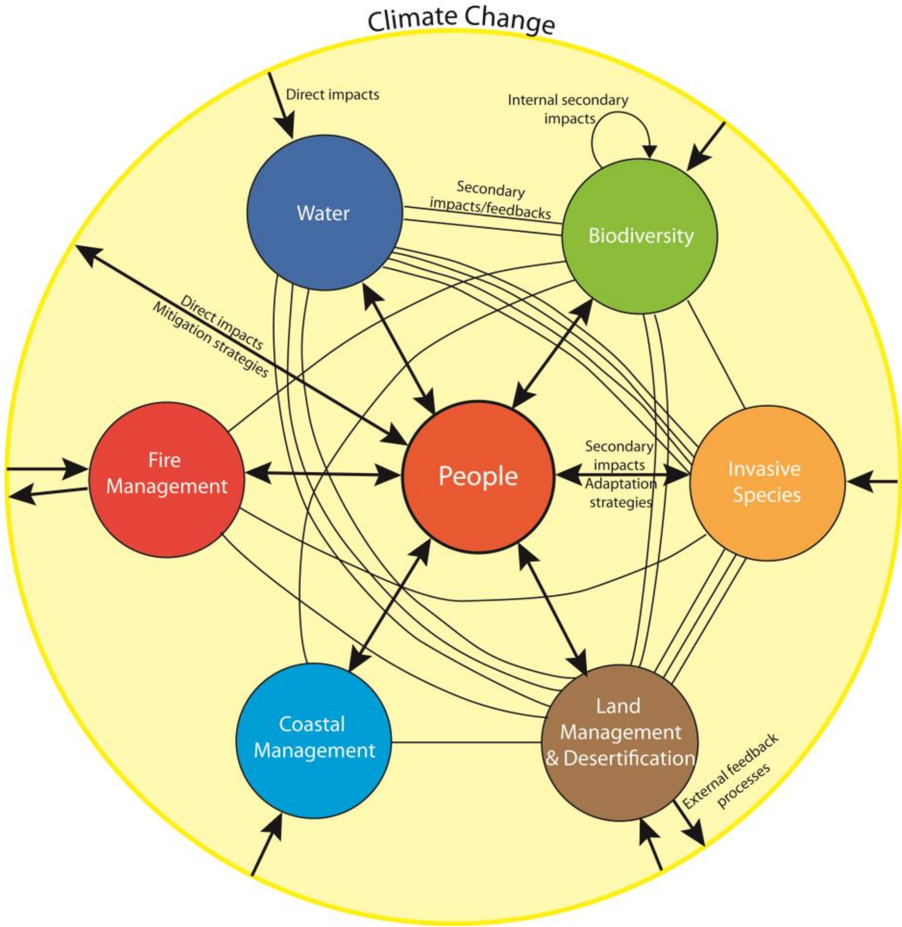
Beyond the pressing need to work more comprehensively with local communities and others for effective NRM outcomes, specific environmental sectoral issues will also need to be managed. Table 6 presents an overview of recommendations made in the vulnerability assessment (Bardsley and Wiseman 2012a), and their alignment with similar actions identified in the existing regional NRM Plan (AW NRM Board 2011). Particular actions within the AW Regional NRM Plan have been allocated a letter relating to the type of action in Table 3 (W = Water (p123) , C = Country (p117), P = People (p111)) and a number depicting its position in the list of actions proposed in the NRM Plan (running left to right across the row). The tabulation of current activities in relation to climate change issues provides a basic quantitative understanding of the existing level of support for climate change-related activities within AW NRM planning documents.

Table 6 Comparison of climate change vulnerability assessment recommendations and existing actions within AW NRM Regional NRM Plan (AW NRM 2011, Bardsley and Wiseman 2012a)

Climate Change Vulnerability Assessment recommendations/suggestions	**Related NRM Strategic Plan Actions in existing Plan**
Flood mapping	W22
Monitoring of Surface and Groundwater Resources	W3, W4, W5, W6, W9, W10, W11, W12, W13, W15, W19, W21, W23, W24
Focus Management on Long-lived Surface waters	W3, W5, W7, W8, W10, W21, C3, C9
Climate knowledge and biodiversity indicators	C7
Protecting key biodiversity assets	C1, C3, C4, C9, C10
Undertake and repeat Biological surveys	C5, C24, C27, P13
Invasive species knowledge	P20
(Over)exploit what you have got: the hunting, harvesting and commercialisation of invasive species	None
Incorporate climate change into stock management practises	None
Determine, monitor and assess key slow variables and thresholds of desertification processes to determine long term drivers of change	None
Monitor dune movement and cliff retreat	None
Establish retreat zones for coastal retreat	None
Fire management	C10, C12
Communication / Engagement Strategy	P6, P12
Maintenance of traditional ecological knowledge	P7, P18, P19
Education, training and employment	P3, P5, P10, P26
Enhancing resilience in communities to climate change	None

The associations between climate change adaptation needs and current planning goals in Table 6 suggest that there is generally strong alignment between the recommended adaptation goals from the vulnerability assessment and AW NRM planning in relation to Country and Water. However, the summary also reinforces the fact that goals aimed at the relationship between people and climate change are not as well developed as those relating directly to ecological concerns. While the social-ecological issues obviously overlap, there is a need to ensure that communities are engaged and supported to own climate change as an issue and to implement adaptation measures. Broad increases in community resilience to climate change are crucial to support effective NRM, given the potential risks to communities associated with a changing climate, and in fact, the apparent existing social vulnerabilities. As highlighted in the vulnerability assessment, people are at the centre of responses to climate change (Figure 6), and this needs to be reflected in any updates to the AW Regional NRM Plan.

Figure 6 Interactive impacts of climate change on natural resource management and social systems in the Alinytjara Wilurara Natural Resources Management region (from Bardsley and Wiseman 2012a)



Suggestions for long-term outcomes, intermediate outcomes, actions and indicators of success for relations between people and climate change are indicated in Table 7, using the same structure as the current NRM Plan.

Table 7 Potential goals for relations between people and climate change

Long term outcomes	People own climate change as an issue, and are supported to take steps to proactively adapt to change and mitigate emissions
Intermediate outcomes	People are aware of climate change, the likely changes that will take place where they live, and of adaptation actions that can help them cope with these changes
Actions	• Awareness raising and engagement to begin conversations about climate change in communities, using interpretation where required • Targeted participatory adaptation projects and activities to manage pressing concerns • Community-based monitoring programs which involve Anangu in the observation and learning from changes in their local environments • Evaluation and communication strategies which present information about what the AW NRM organisation is doing in relation to climate change – both in Pitjantjatjara and English
Indicators of success	• Number of people talking about and understanding climate change issues • Number of people actively involved in adaptation project activities and community-based monitoring programs • Number of people seeking information on AW NRM activities in relation to climate change • Measurable improvements in the resilience of local communities in the context of environmental hazards and change – especially the ability to cope with extreme events (e.g. fire, flooding, heatwaves)

There are also some additional gaps in the existing AW Regional NRM Plan identified in Table 6 relating to vulnerability assessment recommendations, including:

- commercialisation / hunting / harvesting of invasive species
- incorporation of climate change into stock management practices
- assessment of slow variables of desertification processes
- monitoring of dune movement and cliff retreat
- the establishment of retreat zones for sea level rise,
- enhanced community resilience to climate change.

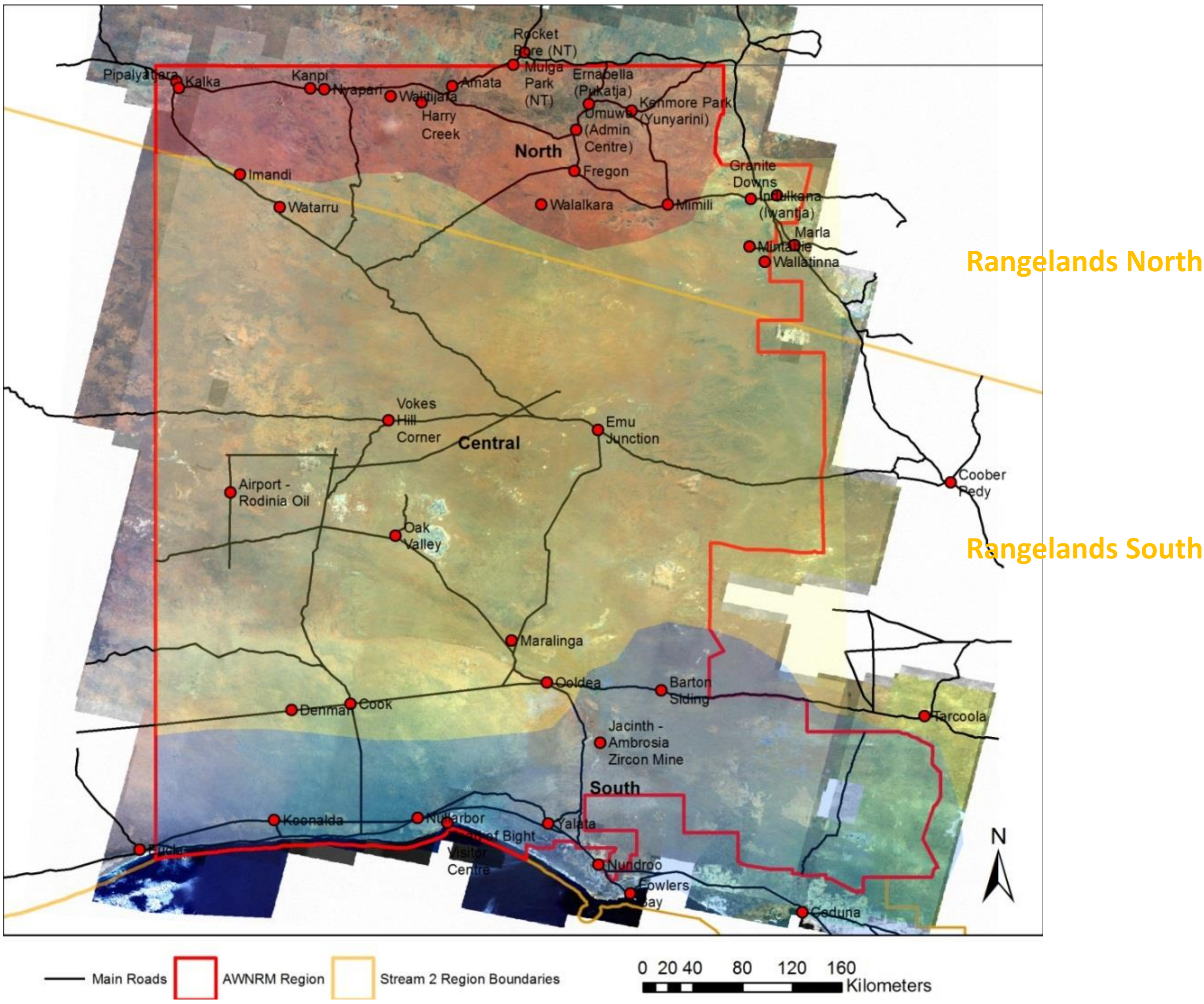
The gaps between the current planning goals and the needs for future climate change adaptation are expanded on in Section 4 of this report to highlight potential additions and/or changes to future AW NRM planning.

3. Climate change in the AW NRM region

3.1 AW NRM climate

The AW NRM region covers over 250,000km^2, and spans three recognisable climatic sub-regions on a north-south gradient (Figure 7). As in previous work (Bardsley and Wiseman 2012a), this addendum makes a distinction between the summer rainfall-dominated north of the region (including the APY ranges), and the winter rainfall-dominated south. In addition, a transitional sub-region is delineated, within which no strong seasonal dominance is present. The distinction between the Rangelands North and Rangelands South zoned boundary from Stream 2 climate change projections are also identified. While the climatic boundaries have been developed from Bureau of Meteorology (BoM) 30-year average rainfall and rainfall seasonality maps, they are intended as a general indication of the types of climate experienced at a sub-regional scale, and are not intended for detailed (e.g. property-level) planning purposes, given the wide variation in microclimates across the region.

Figure 7 – AW NRM region indicating summer rainfall-dominated north (red), transitional central (yellow) and winter rainfall-dominated south (blue) sub-regions; Stream 2 boundaries between Rangelands North and Rangelands South are shown in orange.



The characteristic climatic differences between these three zones in the AW NRM region are summarised in Table 8.

Table 8 Climate zones of the AW NRM region showing rainfall seasonality, variability and other key differences

Zone	Seasonal rainfall dominance	Annual rainfall variability[1]	Average Annual Rainfall[2]	Dominant climate driver(s)	Characteristic rainfall	Other characteristics
North	Summer	High moderate to very high (1.0-2.0)	200-300mm	Australian monsoon, moderated by ENSO	Typically warm-season thunderstorm-type rain, very patchy in space and time. A significant proportion of the year's rain can fall in one rain event.	Warm average temperatures mean rainfall can trigger pulses of growth at any time of year, and when combined with significant redistribution (run-off/run-on) processes due to varied topography, can lead to growth pulses even from small localised rain events.
Central	None	High moderate to high (1.0-1.5)	Less than 200mm	Influenced by both North and South climate drivers	Rain can occur at any time of the year, but very variable	Absence of significant ranges limits large-scale run-off/run-on processes, and reduces the possibility of orographic rain.
South	Winter	Low moderate to moderate (0.5-1.0)	200-300mm	Driven primarily by annual oscillation in Sub-tropical ridge and polar fronts, moderated by ENSO	Typically cool-season frontal system-type rain. More consistent than North (i.e. less patchy in space and time), but consequently lower maximums (i.e. 50+mm over 5 days is very rare)	Cooler winter months mean growth pulses from rain are slower during these times – autumn and winter rainfall is thus crucial for warmer spring growth. Flatter topography limits large-scale run-off/run-on processes.

1. The rainfall variability index is calculated by following the equation 90p-10p/50p, where 90p, 50p and 10p are the 12-month 90th, 50th and 10th rainfall percentiles respectively. Index numbers were taken from Bureau of Meteorology, Rainfall variability map, http://www.bom.gov.au/jsp/ncc/climate_averages/rainfall-variability/index.jsp?period=an#maps

2. Given the large inter-annual variability in rainfall, the rainfall averages are rarely experienced in the North and Central zones, (where single rainfall events can comprise the majority of the year's rain) but are more common in the South.

3.2 Observed climate change

As previously outlined in the executive summary, the climate has already changed in Australia over the past century. In the AW NRM region, average temperatures have risen between 0.5°C and 1.5°C since 1910 (BoM and CSIRO 2014) at a rate of 0.05-0.15°C per decade (Figure 1). The AW NRM region has also experienced a wetting trend in more recent decades, particularly in the north during summer months, possibly as a result of a strengthening of the summer monsoonal system in northern Australia (BoM and CSIRO 2014) (Figure 2).

3.3 Future climatic changes

As part of Stream 2 of the Australian Government's Regional NRM Planning for Climate Change Fund, CSIRO and BoM have developed new projections for the Australian Rangelands which are divided into two zones spanning the AW NRM region (Table 9), and represented in Figures 3 and 7 as Rangelands North and Rangelands South (CSIRO 2014). The climate projections represent best estimates[1] of future climate change. Both climate zones display overall trends, which are summarised according to the general climate change features in Table 9. Detailed descriptions of two climate change emissions scenarios, one representing a reduction in emissions and stabilised climate by 2100 (RCP4.5) and one representing little curbing of emissions and no climate stabilisation (RCP8.5) are also summarised for the two zones.

Table 9 Climate projections for North and South Zones developed from Stream 2 data (CSIRO 2014)

	Overall trend	Scenario	Variable	2030	2090
North	Hotter, possibly more regular large downpours in summer, but generally drier	Late century emissions stabilisation (RCP4.5)	*Temperature:*	Warmer	Hotter
			Rainfall:	Little change to drier	Drier (but with some uncertainty)
		High emissions (RCP8.5)	*Temperature:*	Warmer	Much hotter
			Rainfall:	Little change to wetter (but with large uncertainty)	Drier (but with large uncertainty)
South	Hotter, drier, rising sea levels along coast	Late century emissions stabilisation (RCP4.5)	*Temperature:*	Warmer	Hotter
			Rainfall:	Little change to drier	Drier (but with some uncertainty)
		High emissions (RCP8.5)	*Temperature:*	Warmer	Much hotter
			Rainfall:	Little change	Little change to much drier (but with large uncertainty)

[1] *These projections have been developed by using results from the "best estimate" case in the CSIRO Climate Futures framework, i.e. the climate future representing the maximum consensus of climate models. However, some climate futures do not show clear best estimate and in such a case it is noted that there is uncertainty associated with the projection.*

Definitions

Temperature (annual average): Warmer: 0.5-1.5°C; Hotter: 1.5-3°C; Much hotter: > 3°C

Rainfall (annual average): Little change: -5 to 5%; drier: -15 to -5%; wetter: +5 to 15%; much drier < -15%

The overall zoned climatic trends have been translated into likely impacts on rainfall and temperature for each of the three climatic sub-regions of the AW NRM region (Table 10).

Table 10 Summary of projected climate change impacts on temperature and rainfall for the three climatic sub-regions of the AW NRM region

Sub-region	***Likely climate change impacts on temperature***	***Temperature comments***	***Likely climate change impacts on rainfall***	***Rainfall Comments***
North	• Temperature will increase in all seasons, with fewer cold days and more hot days • Heatwaves are likely to increase • Frosts may counter-intuitively increase due to large high pressure systems blocking cloud formation • Higher potential evaporation rates will reduce the permanency of open water sources (rockholes etc.)	Across all climatic sub-regions of the AW NRM region, temperatures are projected to get hotter. The North is likely to experience a larger increase in the number of heatwaves than the South (Bardsley and Wiseman 2012a)	• Rainfall will become more variable, with more intense extreme events and longer periods between rains • Potential increases in summer (Nov-Apr) rainfall due to strengthening monsoon, which will lead to bigger extreme events, but overall drying trend likely.	The high natural rainfall variability of this zone is likely to mask any trend in average rainfall (due to climate change) for some decades to come, particularly in the summer season. Since ecosystems are already adapted to high natural variability, this confers some adaptive capacity
Central	• Temperature will increase in all seasons, with fewer cold days and more hot days • Heatwaves are likely to increase • Higher potential evaporation rates will reduce the permanency of open water sources (rockholes etc.)		• *Rainfall will become more variable, with more intense extreme events likely* • *Uncertain overall trend in rainfall*	Ecosystems in this zone are already adapted to high natural rainfall variability, which confers some adaptive capacity to climate change
South	• Temperature will increase in all seasons, with fewer cold days and more hot days • Heatwaves are likely to increase • Higher potential evaporation rates will reduce the permanency of open water sources (rockholes etc.)		• Rainfall will become more variable, with more intense extreme events likely • Winter and Spring rainfall likely to decline more than in other seasons	Ecosystems in this zone are more dependent on regular winter rainfall, and are likely to be much more impacted by changes in both the variability and amount of rainfall compared with the central and northern zones

At a region-wide level, concentrating efforts in the southern climate zone to adapting to decreased rainfall in the winter growing season may need to be a priority, whereas in the northern climate zone, where rainfall is naturally highly variable, efforts could focus more on coping with hotter temperatures and heatwaves, and the risk of extreme rainfall events that, in turn, could increase the frequency of large floods and fires.

The changes in temperature and rainfall will also have secondary impacts on ecosystems in the region, and these are discussed in the following section in relation to stakeholder concerns and adaptation options.

4. Stakeholder concerns and adaptation options

Workshops with stakeholders from AW NRM and Aṉangu Pitjantjatjara Yankunytjatjara (APY) Land Management staff, scientists and indigenous communities were run initially in 2011 and more recently in 2014. Those workshops identified a number of themes that people felt were important in the context of a hotter and more variable rainfall climate (see Appendix 2 for a list of responses grouped by community). These themes are discussed in detail below in relation to likely climate change impacts and recommended adaptation responses. Each theme follows a "state, issue, response" format where the current state is illustrated using stakeholder responses, the issues associated with climate change impacts are briefly described, and then potential adaptation responses are highlighted. Summaries of these themes are presented in Section 4.11. Quotes presented in the text outline the source place and date of the information provided in workshops and interviews.

4.1 Buffel grass

Buffel grass (*Cenchrus ciliaris*) was consistently raised as the major cause of environmental degradation in the AW NRM region by land managers and communities. Buffel grass increases the fire risk around communities, destroys native vegetation by changing the fire ecology of the areas it invades, and reduces native grasses which impacts upon herbivores such as *maḻu* (red kangaroos) and *warru* (black-footed rock wallaby). The following statement is typical of the concerns raised (Ernabella 2014):

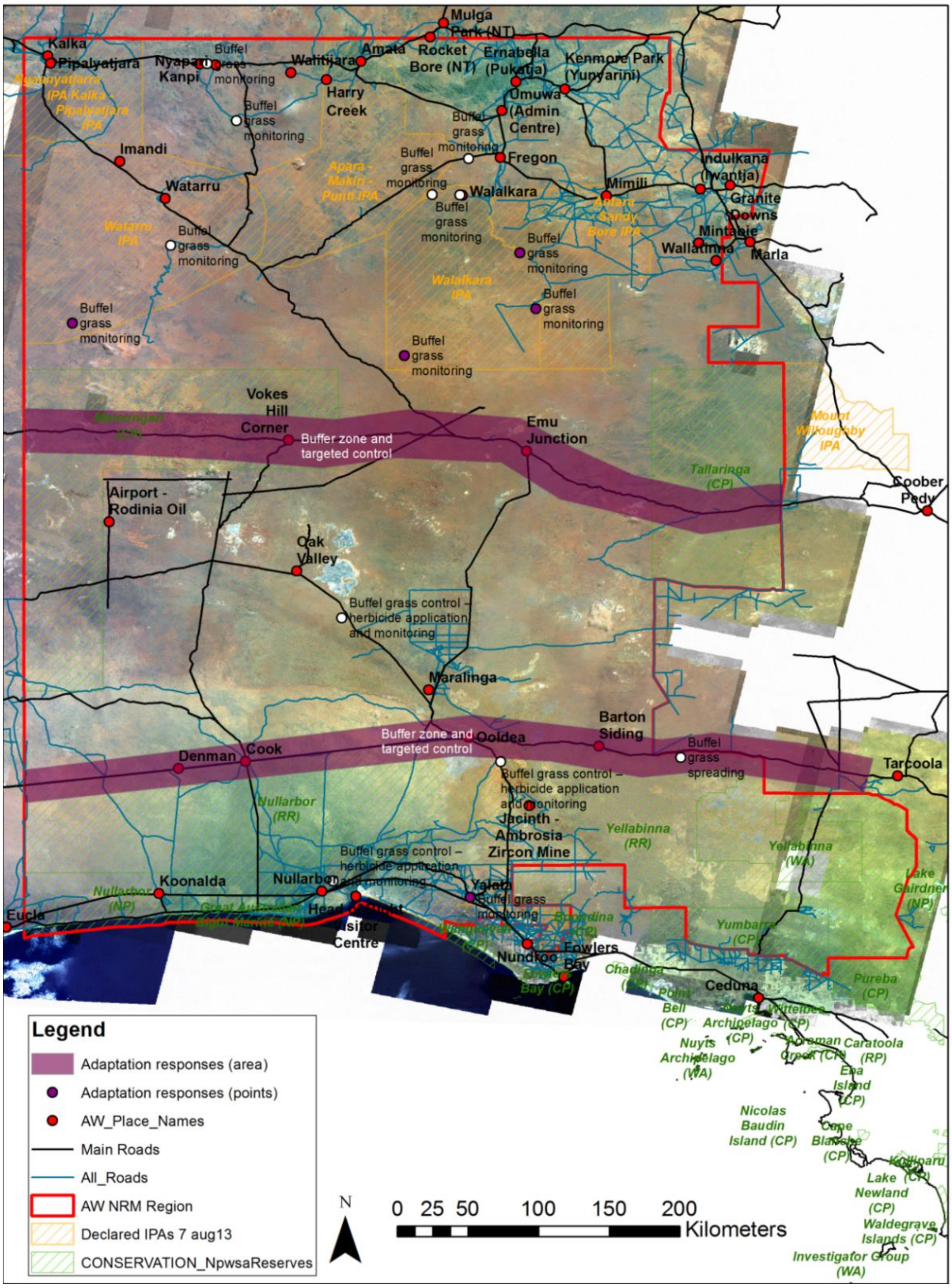
> *There is a big problem with native animals now, there are not many around. Emu, malleefowl and turkey have all gone with the buffel grass. First when buffel and camels came into the lands we didn't know everything about them. Buffel grass is a big problem everywhere. People are allergic to buffel grass. In the 1980s my Grandmother used to show me the flowers, but now they have gone, even the animals have gone. We don't find wild onions in the ground anymore. The buffel grass is drying up everything.*

Climate change is likely to exacerbate the spread of Buffel grass, as it is a C4 grass which thrives in hot conditions and increased CO_2 levels, and is well adapted to variable rainfall and fires (Scott 2014, see Figure 8). Modelling indicates Buffel grass is likely to move further south with future climate change (Scott 2014).

Figure 8 Projected Buffel grass distribution in AW NRM region by 2070 (A1B emissions scenario, data from Scott 2014)

At a sub-regional level, focussing efforts at monitoring and containing Buffel in the APY Lands and preventing it from spreading south into areas such as the southern parts of Walalkara, Watarru and Antara-Sandy Bore Indigenous Protected Areas should be a high priority (Figure 9). Efforts could focus on drainage lines and roadways, and particularly the intersection between these two dispersal pathways (Marshall 2013). Monitoring techniques should be chosen to limit the spread of seed material into potential undisturbed areas – aerial surveys in the more remote and inaccessible parts of these IPAs would be preferable (see Marshall 2013 for development of these survey techniques). In the Southern AW NRM region, preventing Buffel grass from spreading south of the railway line is already also a high priority, and those efforts should be supported.

Figure 9   Current Buffel grass monitoring activities (white) and future priority management and monitoring areas (purple)



Controlling Buffel grass around communities was recognised as a high priority by stakeholders to reduce the risk of fire to key assets such as health clinics, water infrastructure and community housing. In the north, where Buffel is widespread, there is little opportunity for large-scale control, and targeted asset protection (both built and natural assets) is likely to be the only viable control strategy (Scott 2014). Regular grading of two barrier strips surrounding communities provides options to burn the vegetation in-between the strips if required to effectively increase the width of the fire break, or to back burn from communities out to the graded strip to prevent the fire getting away.

The communities are also a significant source of new Buffel seeds. At a local level in the APY Lands, focussing efforts on control within communities and along roadsides would reduce the risk of Buffel grass spreading via cars and trucks. The road from Umuwa to Ernabella, and the main road connecting Ernabella with Amata and Kenmore Park, are used frequently and could be targeted to reduce Buffel grass as well as reducing fire risk (see Section 4.2 below for a discussion of these combined risks). Focusing control efforts on the headwaters of creeks and moving downstream from there reduces the chance of Buffel spreading due to water transport during heavy rains. Creek areas are also key sites for long-lived eucalypt trees which represent significant sources of landscape carbon, and by reducing Buffel grass in these areas, the risk of wildfire and subsequent loss of these species would be reduced. Controlling Buffel grass along creeklines also acts as a fire break and buffer to reduce the spread of large wildfires.

In the south, respondents at Yalata noted that Buffel had been seen for the first time around the community, most likely brought in on cars from further north (e.g. Oak Valley). Targeting control around Yalata could prevent it from spreading out from this community in the South, and could also be a high priority for management.

4.2 Fire management

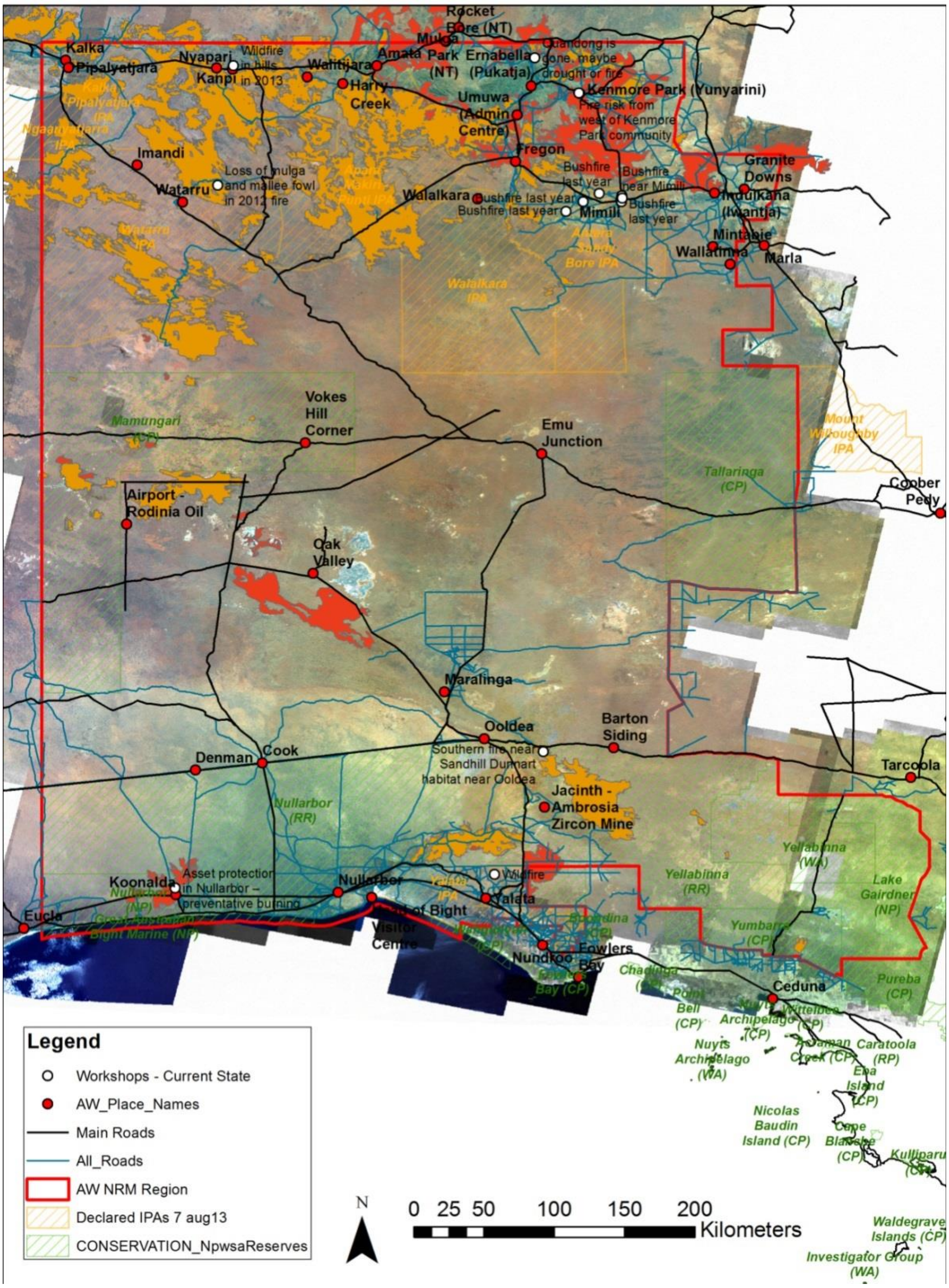
Improved fire management was considered a high priority for land managers both in the southern part of the AW NRM region around Yalata and in the north in the APY Lands. In the south, fire management is largely reactive at present, although there is a strong desire to be able to do more proactive prescribed burning, with respondents from Yalata (2014) stating:

> *We are not doing much burning of vegetation, we mostly fight fires. October is the best month for controlled burning. All the wildfires come out of the Conservation Parks. People worry about the fires. There have been two big fires through the grasslands in recent years. Two years ago you could see the flames from Yalata, but the fire was still 20 kilometres away. There are a few small fires in the community, but they are easy to put out. We control fires by burning out from tracks which we use as fire breaks. We have one 1000 litre truck, which is bad and doesn't go everywhere. We have 800 litre tanks on the back of four utes and they are great, they go everywhere. We aim to designate a fire shed but if people aren't used to using it, it is hard to fight fires.*
>
> *If we did some more controlled burning we would target the IPA boundaries where there is grassland. If it gets warmer earlier with climate change, we will need to control earlier. This area was always a bit different for burning.*

In the north, the number one priority for land managers was to increase funding to proactively manage fire, to reduce the incidence of huge wildfires which destroy important habitat such as *nganamara* (malleefowl) nesting sites in mulga woodland in Watarru IPA (see Figure 8). This priority was echoed by CFS staff, who noted the damage and financial cost wildfires had on community infrastructure was because there wasn't adequate preparation or response capabilities:

> *The 2012 fire was devastating as it whipped through communities. There were only a few people here in summer 2012 when the fire came through. They evacuated Kalka but it just burnt through the lands with little opportunity to fight it. There is only one small truck to fight fires with from Ernabella, which is really nothing.*

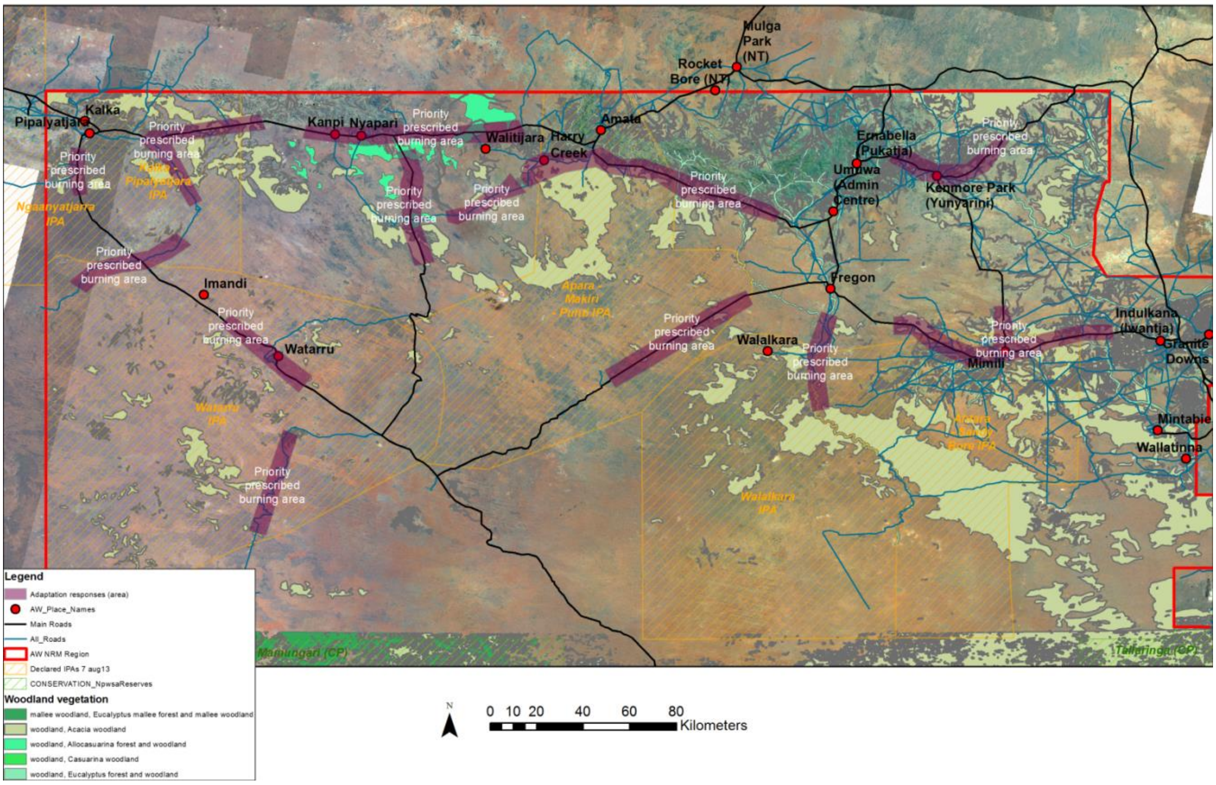
Figure 10 Recent large fires (2011 in orange, 2012 in yellow) in the AW NRM Region, and stakeholder observations of impacts (white circles).



Fire risk is likely to increase in a changing climate, particularly in the north of the region, due to a combination of hotter temperatures which extend the fire season and increase the number of extreme fire weather days, larger summer rains which will increase the amount of biomass and hence fuel loads, and the predicted spread of Buffel grass (Bastin 2014a). These combined factors necessitate a much greater focus on proactive/preventative fire management, given that even under current climatic conditions fires are regularly burning large parts of the northern AW NRM region.

At a sub-regional scale, future fire management in the north should be concentrated along major roads, as these are the most common areas of ignition, and they are also commonly infested with highly flammable Buffel grass (Figure 8). Roads can also provide important firebreaks. The roles of firebreaks could be enhanced by grading a strip parallel to roads on one or both sides, perhaps in association with telephone line corridors, which could offer more control and options for fire management (e.g. burning the strips to increase the firebreak, back-burning, etc.) (Figure 11). Controlling Buffel grass in these areas, perhaps through a combination of burning and herbicide spraying, would reduce fire risk and also reduce the spread of Buffel as the roadways are the largest source of seed dispersal (see section 4.1). Prescribed burning around important sites, such as the mulga woodlands in Watarru IPA, and the Desert Oak (*Allocasuarina decaisneana*) forests around Ka<u>n</u>pi-Nyapa<u>r</u>i (which are relatively uncommon in the APY Lands) was also recognised as a priority by land managers.

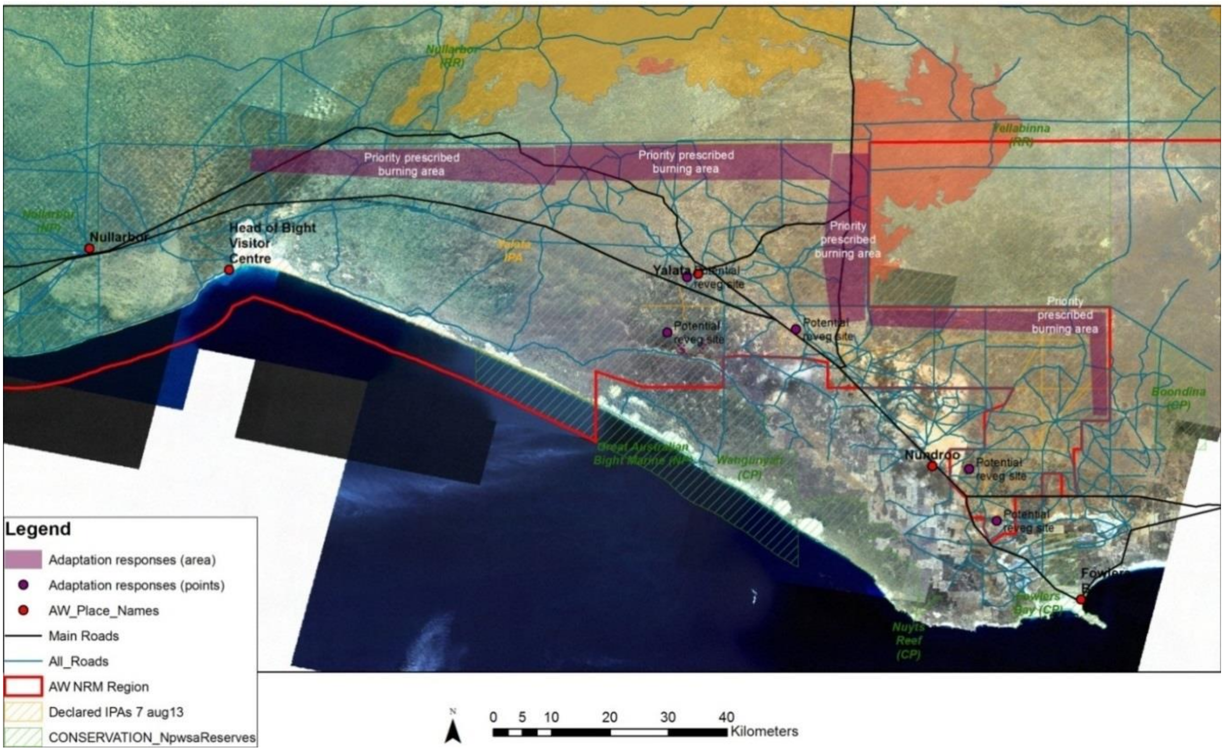
Figure 11 Example of priority areas (purple) for future prescribed burning in the APY Lands, taking into account roads and adjacent woodland vegetation (green shades).



At a local scale in the North, ensuring that the majority of communities have trained, capable Country Fire Service (CFS) units with response vehicles could be a high priority to ensure quick response times in the inevitable event of a fire within or close to communities. The process of developing such CFS units is currently underway and may just require some further support.

In the South, focussing fire management in the north-eastern corner of Yalata IPA and Yellabinna and Yumbarra conservation parks to reduce grass fires could be prioritised, given that fires seem to be generated within adjacent conservation reserves (Figure 12). Additionally, this strategy will help to protect potential future carbon plantings which have been proposed for the south-east of the IPA (see Section 4.10). Increasing the number of strategically located shed tanks would help to increase the range and water capacity of vehicles able to fight fires in these areas. As with the North, there needs to be greater funding for training and coordinated responses to fire through local CFS teams in the South. In just one example, the only fire refuge near Yalata is presently in Nundroo, about 60 kilometres away from the largest community in the South.

Figure 12   Example of priority areas (purple shaded areas) for future prescribed burning in Yalata IPA, based on fire sector risk from the north (2011 fire shown in orange, 2012 fire shown in yellow), and the need to protect potential carbon planting assets (purple circles) in the south-east of the IPA.



Overall, funding and technical support for proactive fire management (e.g. strategic controlled burning and other fuel reduction strategies) could be made available after substantial and extended periods of rainfall, as it is after such rains that large wildfires are most likely due to the significant build-up of dry biomass (Bastin 2014a). A fire fund which is tied to seasonal rainfall observations could help to meet the need for large scale fire management after irregular rains. By accumulating regular (i.e. annual) funding, but accessing such a fund or trust only after significant prolonged rainfall, it could provide a financial mechanism to increase fire management activities as required during these critical times. Appropriate controlled burning of landscape would help to build resilience to the extreme fires already experienced in the region, and help to mitigate against a future increase in fire risk. The timing of proactive fire management is likely to become even more critical in a changing climate as the window of opportunity for safe prescribed burning is likely to contract due to warmer temperatures (Bastin 2014a). Monitoring seasonal outlooks and forecasts and longer term climatic trends (e.g. ENSO and SOI indexes) could help to more accurately plan the best burn times.

4.3 Heatwaves

Heatwaves have been a particular concern for indigenous communities and land managers in recent years. For communities, heatwaves make it difficult to go outside or continue their activities, and can lead to blackouts due to high electricity loads from air conditioner use. For land managers, heatwaves make working on country very challenging, and present real risks to people and property. For example, the concern was raised in Yalata (2014):

> *Heat waves make it very difficult to work. It is difficult for tourists and the local community. People have crap cars and they have breakdowns, which is why we are putting water tanks up everywhere. We are putting them up where people go hunting. Also, water is a very important tool for NRM, we fight fires, fill up our weed sprayers etc. When it is too hot and it is declared a catastrophic fire danger day, the NRM people aren't allowed to go out, but we have to go out because we have responsibilities* [to the community]*. The hottest day out here was 52 degrees – its gets hot! Fire isn't the real problem it is dehydration and the heat itself. When the fire started 2 years ago in Yellabinna Conservation Park the Park rangers couldn't come out and help us fight the fire over here because it was a catastrophic fire danger day – but could we just wait for it to burn?!*

Climate change is likely to increase the number of heatwaves across the region, particularly in the north, as well as increasing the average length of heatwaves over time (Bastin 2014b). This trend has been observed in Giles to the NW of the AW NRM region, with heatwaves becoming longer in the recent past compared with heatwave records for the beginning of last century (Bastin 2014b). Overall temperatures will increase, and hotter nights will prevent things cooling down as much before the next day begins.

At a sub-regional scale, the most important adaption response to heatwaves is to guarantee people are safe. Most housing in the region is presently dependent on air conditioning to maintain thermal comfort during the summer months. This presents a risk when electricity supplies fail, as happened in Yalata when the generators supplying power failed due to overuse from water pumps and air conditioners during extreme heat conditions. The whole community had to be temporarily relocated to cope with the heat:

> *We have blackouts in summer. We have three generators and we will have a big test for the new one with the first hot days. People run their electricity and they don't care. There is a water pump in every house which is the big draw of electricity in the summer. We had a blackout and they put people up in Ceduna Foreshore* (hotel) *in the summer.*

Similarly communities in the APY Lands use air-conditioners or move away during the hot summer months, for example at Ernabella (2014):

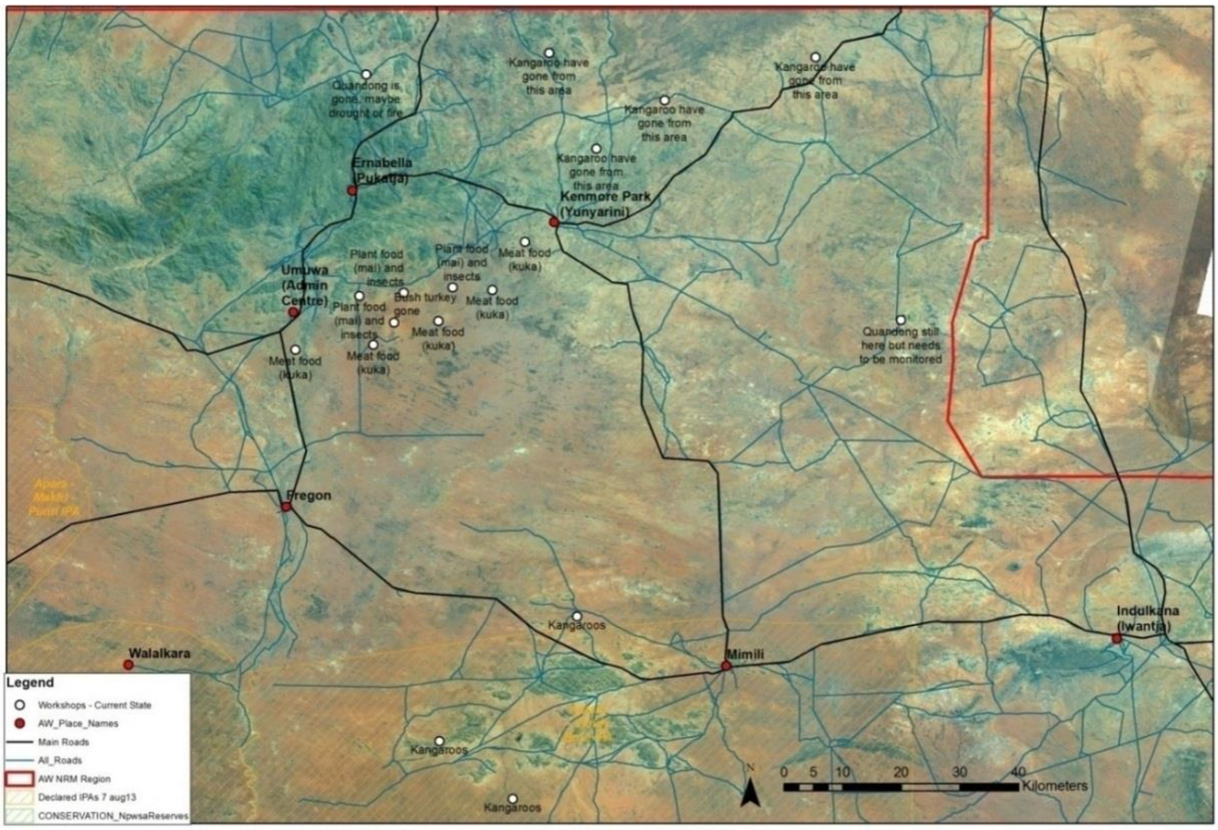
> *Here, when it is very hot we sit in the air conditioning. There is a swimming hole but land management told us not to go there because there was a big crack. They didn't tell us if they could fix it. When it is hot, people also go on holidays to Adelaide, Port Augusta to the beach. In the past people would just go to a cave and lie down but now we go away or use the air con.*

While moving out of communities during summer can be seen as an adaptive response to heat stress, some respondents in the APY Lands indicated they couldn't move during summer due to ill-health, which presents a significant risk to some of the most vulnerable people. Finding ways to reduce the reliance on air conditioning, by improving building thermal performance, increasing shade trees, and improving community health will help people to adapt in place in the longer term (Measham 2014). More swimming pools could be built in communities to enable people to cool off during summer. At times it may also be necessary to consider supporting some appropriate and temporary migration for more vulnerable people, to reduce heat stress and associated risks. Scheduling important NRM activities during the cooler winter months will become even more critical to ensure that people aren't put at risk during the hotter summer months. It may also be necessary to ensure animals have access to sufficient water and shade (see Sections 4.6 and 4.7 for more detail on these types of adaptation responses).

4.4 Bushfoods - hunting and harvesting

All communities and community representatives noted the decline of traditional bush foods, including *kuka* (meat foods such as kangaroo, rock wallaby, emu and bustard) and *mai* (plant foods such as Quandong, native grasses and insects) on their lands. Many reasons were given for these declines, including the spread of Buffel grass, over-hunting, introduction of feral animals, and other changes since European colonisation. As an example, Figure 13 shows reported availability and observed declines in bushfoods in the eastern part of the APY Lands as suggested from workshops.

Figure 13   Bushfood availability and observed declines in the eastern APY Lands



In the south, respondents noticed a similar decline in some bushfoods such as the red kangaroo, attributing it to over-hunting:

> *During summer there is hunting for red kangaroo (Malu) on the plains north of here all the way to Oak Valley. We don't get kangaroo down south anymore because the last ones have been shot out. Just north and further west there is a few.*

Climate change is likely to exacerbate these declines in bushfood availability, as plants such as Buffel grass gain even more competitive advantages over native grasses, and feral animals put more pressure on native plants through overgrazing and browsing (Pavey and Bastin 2014, Scott 2014). In addition, heatwaves are already having a detrimental impact on important biodiversity such as bushfoods - an impact which could be expected to increase with future climate change. For example, it was stated in Ernabella (2014):

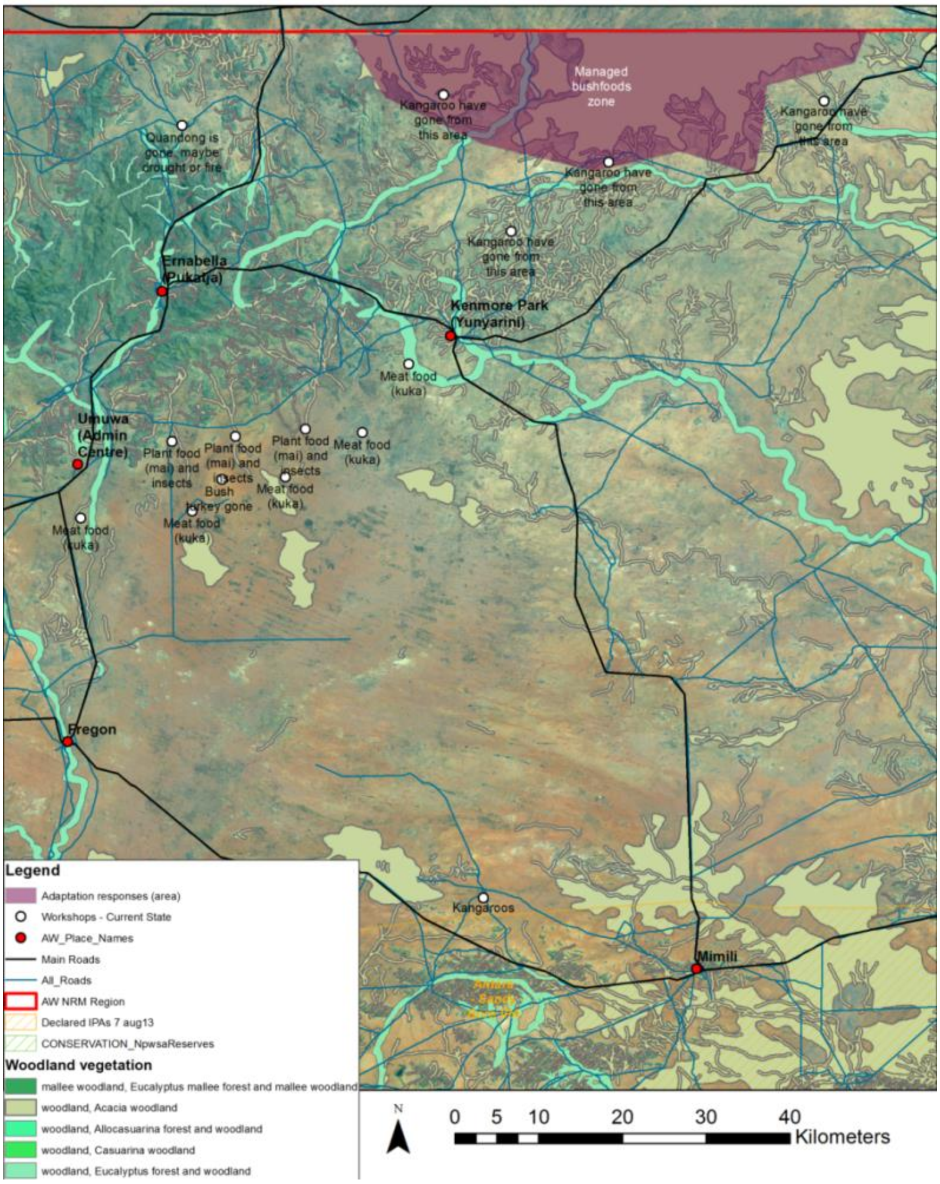
> *Kangaroos died with the extreme heat last summer. When it reached 50-51 degrees Celsius they dropped dead. That is pretty hot, you can't do anything.*

At a subregional scale, fire management which aims to reinstate traditional fire mosaics could have significant benefits for bushfoods, as many of these plants and animals are adapted to relatively regular burns associated with traditional aboriginal management of country. However, warmer temperatures and the spread of Buffel grass will mean that the traditional seasonal periods in which burning used to occur will become shorter, and that wildfire may become more regular due to the ability of Buffel grass to regenerate quickly after fire and rain. Hence, monitoring post-fire recovery of plants and animals is an important priority for the effective use of controlled burns for biodiversity and bushfood benefits. Utilising existing photopoints for assessing threatened species and grazing impacts could help to coordinate longer-term monitoring data. Managing feral animals (see Section 4.8) will also have adaptation benefits for plants and animals by reducing competition for food and the impacts of grazing/browsing.

At a local scale, land managers could work with communities to designate and agree upon areas where hunting is controlled and other threatened processes are managed. For example, Ernabella (2014) community members indicated that conservation efforts should be focussed mostly in the north-east as this is where there are more trees and bushfoods available (Figure 14):

> *Around the community to the east should be the main area for conservation, but everywhere is important and everywhere needs more conservation for bushfoods. We still go hunting but it's out of this area to the northeast where there are more trees.*

*Figure 14   Example of a managed bushfood zone to the northeast of Ernabella, focussing on mulga (*Acacia aneura*) woodland areas as regions of higher bushfood availability, but also at higher risk due to a changing climate*



In the south, a similar area for biodiversity management for bushfoods could focus on ground-water dependent vegetation to the north of the Nullarbor Plain (see Section 4.10 Biodiversity and Carbon).

By managing hunting pressure, grazing, fire, water resources, Buffel grass and feral animals more intensively in designated areas, communities could ensure desired species such as kangaroos have a greater chance of increasing their populations, providing more hunting opportunities for people living around these managed zones. Such zones could act as refuges, where non-climatic threats are minimised to enhance the resilience of animal populations to climate change. Monitoring indicator species, such as Quandong, could be a way to quickly assess impacts from feral camels and guide management decisions. The mulga (*Acacia aneura*) woodlands to the northeast of Ernabella (see Figure 14) are at high risk due to changing fire regimes as a result of climate change, and so targeting management in that area would offer carbon mitigation benefits, as well as supporting the adaptation of biodiversity and communities to environmental change.

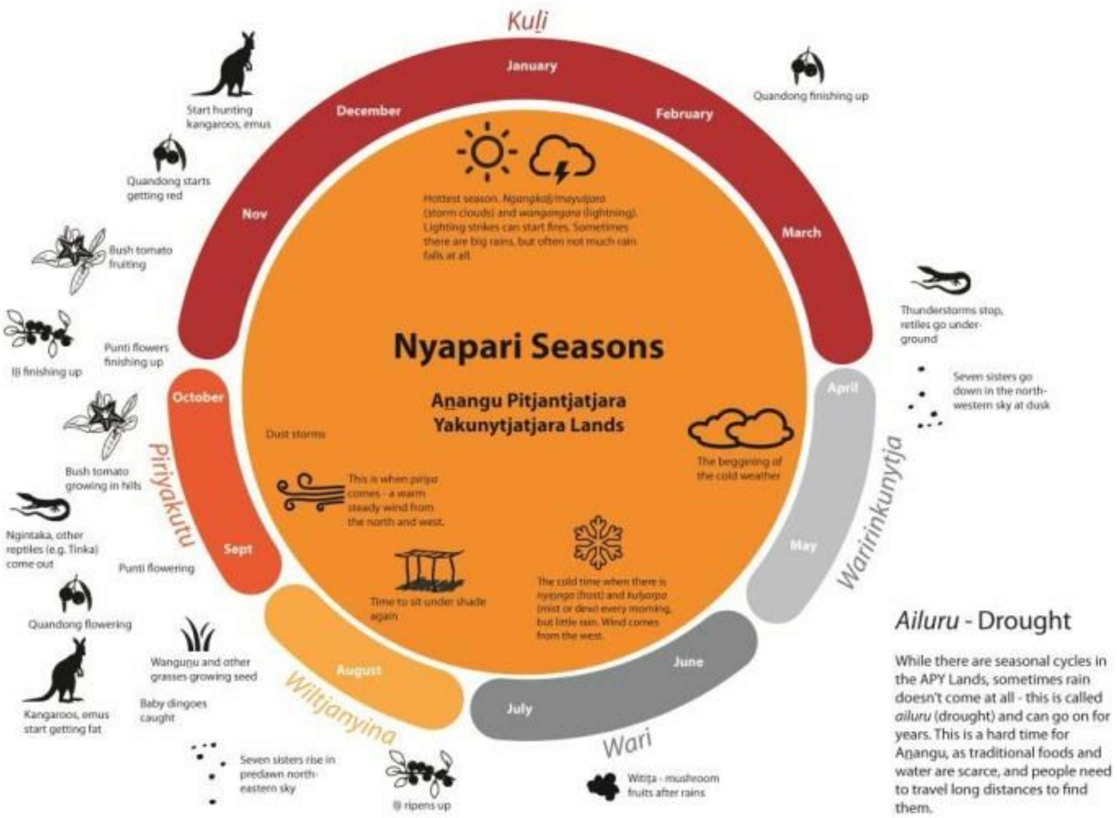
4.4.1 Observing the seasons and signs

> *The weather is getting warmer. Spring is rushing now, it is coming quickly, summer is coming quickly. The seasons used to be more even, more spread out.*

While spatial patterns are important, the timing of events are just as important to A<u>n</u>angu, and they have an intimate knowledge of when things are ripening up or ready to hunt – knowledge which is connected to the stars and movement of the constellations in the sky throughout the year. However the traditional reliance on the stars to forecast when the seasons are changing may not always hold true in a changing climate, which, as A<u>n</u>angu have observed, may have earlier springs, longer summers and shortened autumns and winters. Thus there is a need to keep track of the changing seasons, to see over time what key indicators of seasonality are changing, and to adapt to these changes.

Using seasonal calendars (Figure 15) as a monitoring tool in schools and communities could help to track changes in bushfoods and other seasonal phenomena. Each year could be recorded on a new calendar, and a compilation of multiple years would indicate gradual trends in the timing of events over time.

Figure 15 Example of seasonal calendar developed from workshop in Nyapa<u>r</u>i



Recording seasonal events also has the benefit of supporting people to observe particular elements as they are out on country, and in association would assist in the transfer of traditional knowledge between generations. The simple and graphical format of a seasonal calendar is accessible for all ages and only requires basic levels of English proficiency, and references to key elements could be linked to existing data-entry programs in use in the AW NRM region such as CyberTracker.

4.5 Threatened species and other species of concern

Previous work by Robinson et al. (2003), as well as summaries undertaken in Bardsley and Wiseman (2012a) have outlined a range of threats to the biodiversity in the AW NRM region. The analysis undertaken here aims to more specifically identify how threatened species and other species of concern raised in community workshops interact with climatic drivers, in order to suggest management strategies to help them adapt to climate change. Given the lack of baseline information and basic scientific knowledge available for particular species, the reviews presented below remain preliminary in scope. More detailed on-ground ecological assessments with traditional owners will need to be conducted on species that are considered to be particularly at risk due to climate change.

Overall suggested management strategies to protect threatened species in the context of future climate change are similar to what is currently considered best-practice for rangeland management. Those approaches emphasise the need to manage fire to create a patchwork of different fire seral stages and to protect fire-sensitive habitat, and to manage feral animals and Buffel grass to reduce the non-climatic threats to the threatened species. While these activities already take place in the AW NRM region, the emerging climatic risks suggest that they will need to be scaled up to address existing challenges as well as future change.

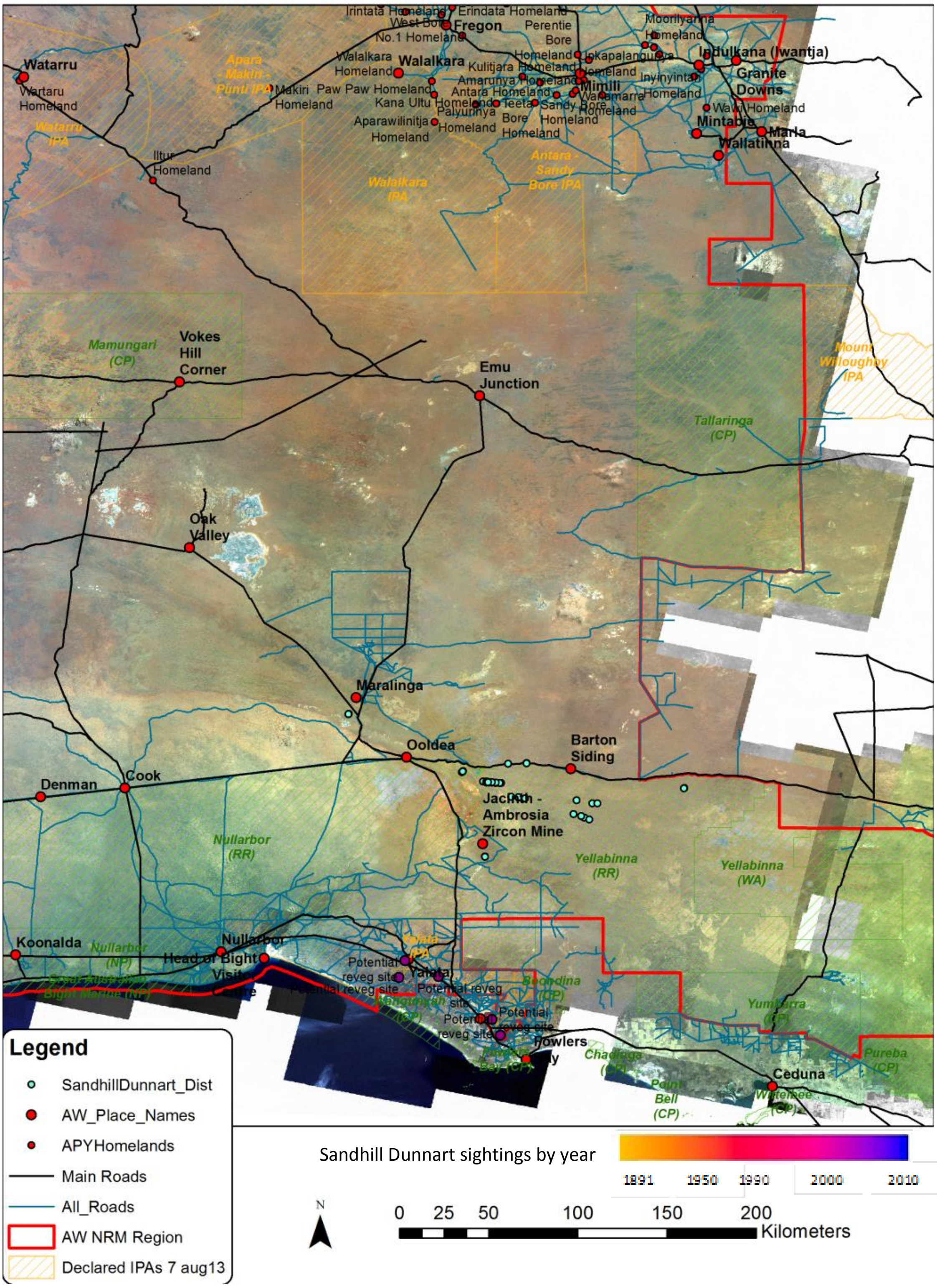
Patch burning in the APY Lands

4.5.1 Sandhill Dunnart (*Sminthopsis psammophila*)

Threat Rating: Rated Vulnerable (SA), Endangered (Australia wide) (NRM Plan 2011)

Distribution: Sandhill Dunnarts have been recorded to the south-east of Ooldea in the south of the AW NRM region. (Figure 16)

Figure 16 Sandhill Dunnart recorded sightings in the AW NRM region (data source: ALA 2014)



Ecology and climate interactions

Sandhill Dunnarts either burrow or shelter under large spinifex clumps, generally residing in areas of spinifex that have been established for at least 8 years since last being burnt (Figure 12)(Ward et al. 2008). In the southern Great Victoria Desert, Sandhill Dunnarts burrow underneath much older spinifex, but in the Eyre Peninsula, they shelter in the Spinifex grass itself rather than burrowing, and tend to utilise younger (8-20 year) spinifex (Churchhill 2001) (although McLean's (2012) findings of Sandhill Dunnart preference for 60+ year-old spinifex in the Eyre Peninsula indicate that there may be more factors influencing habitat choice than post-fire spinifex age alone). While explanations for the different nesting behaviours between the two regions have not been tested, Churchill (2001) suggests that soil temperatures on Eyre Peninsula can be too cold, thus requiring too much energy to keep warm in a burrow, compared with warmer ambient temperatures at Ooldea.

This difference in Sandhill Dunnart nesting behaviour suggests that fire management may be more critical in the Eyre Peninsula to maintain a proportion of spinifex suitable for habitat, whereas in the Great Victoria Desert where burrowing occurs, fire management may not need to be such a priority. This difference could also reflect the fire ecology of the two regions, with the Great Victoria Desert only experiencing large wildfires after a series of wetter years (Bastin 2014a), compared with the Eyre Peninsula which experiences more regular rainfall and hence the chance of more regular biomass growth and subsequent fire. In monitoring programs in the AW NRM region, Sandhill Dunnart populations have been highest in areas where the spinifex cover was greater than 20% of the area surveyed. Spinifex cover appears to be greater in areas of more irregular dune formation compared with more linear dune systems (Ward et al. 2008). Latz (1995) suggests that the spinifex deserts were the only regions likely to have been relatively uninfluenced by Aboriginal burning over millennia due to their lack of water necessary for human survival and travel within these lands. Thus as traditional burning practices have declined following European colonisation, the southern Great Victoria Desert is likely to have been relatively unaffected compared with the northern Great Victoria Desert and Central Ranges which have experienced significant changes in fire regimes and increases in the number of large wildfires (Latz 1995).

Potential climate change impacts

The main threat for Sandhill Dunnart from climate change this century is likely to be from changing fire regimes, which could have a large impact on spinifex habitat availability. Spinifex deserts are still likely to require two consecutive years of good rainfall to promote a biomass growth response which subsequently provides enough fuel to carry a large wildfire (Bastin 2014a). However, when such rainfall does occur, wildfire is likely to be more intense and widespread due to hotter temperatures and higher evapotranspiration rates. Where Buffel grass is present, this will exacerbate the fire risk. This increase in fire intensity and spread may reduce post-fire habitat options for Sandhill Dunnarts, by destroying large areas of potential habitat. Given that Sandhill Dunnarts appear to prefer older spinifex in the Ooldea region, larger fires may destroy habitat areas leading to population losses. In contrast to the threat posed by changing fire regimes, rising temperatures would be unlikely to affect the Sandhill Dunnart population in the AW NRM directly due to their ability to burrow to escape the heat.

Management implications

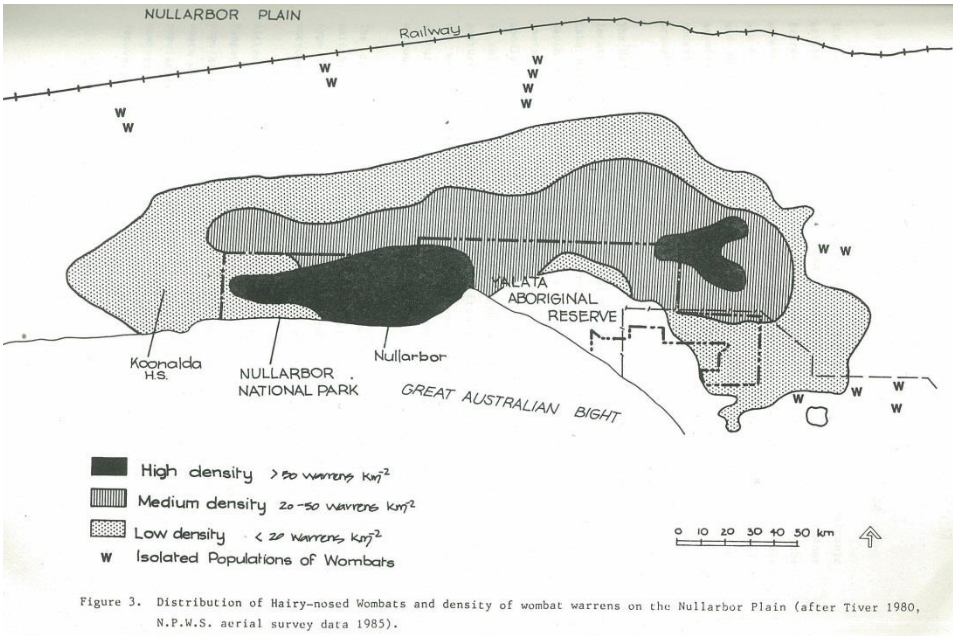
Unlike in the northern part of the AW NRM (APY Lands), and as stated above, the southern Great Victoria Desert is unlikely to have been exposed to Aboriginal burning patterns due to the lack of water available for Aboriginal people to live in this region. Thus while a viable management option in the north of the AW NRM region is to re-instate traditional burning practices in response to climate change to protect native species, there is no such fall-back option available to the southern Great Victoria Desert where Sandhill Dunnart are found. Nevertheless, creating fire breaks along denser stands of spinifex near known Sandhill Dunnart nesting sites could be important to mitigate against large wildfires destroying extensive areas of spinifex. The south-east of Ooldea has typically had the largest recorded Sandhill Dunnart population, suggesting a target area to focus on for conservation activities. However, other sites where Sandhill Dunnarts have been observed also offer the opportunity to trial different experimental management techniques (Read and Moseby 2009). Management activities for Sandhill Dunnart, including creating fire breaks, as well as controlling feral predators such as cats and foxes to reduce non-climatic pressures, are also likely to have benefits for Malleefowl and Marsupial Mole (Ward et al. 2008). Ultimately, more research is needed to determine the habitat preferences of Sandhill Dunnarts and to explore the links between fire regimes, spinifex age and nesting behaviour in order to more accurately assess the implications of future climate change impacts on the species.

AW NRM region: Sandhill Dunnart, Malleefowl and Wombat

4.5.2 Hairy-nosed Wombats *(Lasiorhinus latifrons)*

The highest populations of hairy-nosed wombats (*Lasiorhinus latifrons* Owen 1845) have historically been in the western edge and north-eastern corner of Yalata IPA, although warrens occur throughout the northern region of the IPA (Figure 17). Wombats depend on an availability of green grasses throughout the year to graze on. More regular and longer droughts and overall decreased rainfall as a result of climate change could impact negatively on fodder availability. Increased grazing competition from rabbits may also increase the vulnerability of wombats to climate change. However an adaptation advantage is that wombats are typically semi-nocturnal which minimises exposure to heat stress.

Figure 17 Historical distribution of wombats in the southern AW NRM region, from St. John and Saunders (1989) based on aerial survey data from 1980.



St. John and Saunders (1989) suggest that in the Nullarbor, range expansion is limited in the east by extensive sand dunes, and in the north and west by increasing aridity. As the climate is expected to become more arid, a migration to the south may be necessary, though as St. John and Saunders (1989) note, this is possible only where suitable habitat exists and there are no conflicts with other land uses such as cropping. As a result, the eastern population of wombats in the Nullarbor (Figure 17) will potentially be able to migrate southwards, however the mobility of wombat populations in the western area would be limited by the coast.

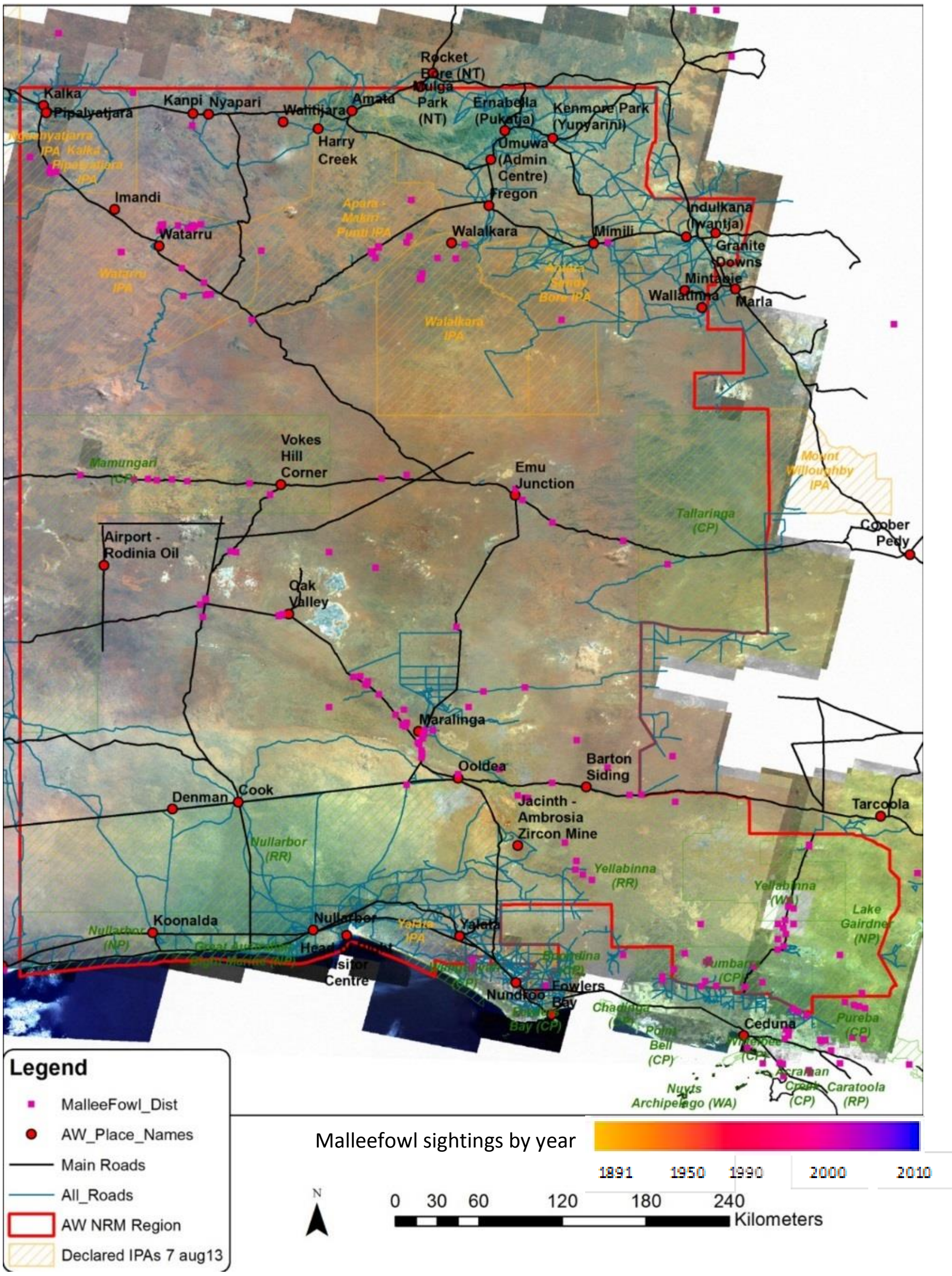
Management implications

Ensuring that clay depressions / pans are protected and are not eroding could ensure more grass production for forage for wombats as the climate warms and dries. Intervening directly and constructing shallow ponding banks could help restore eroded clay pans and increase grass production further (Purvis 1986). Control of rabbits around wombat warrens could be another key adaptation strategy to ensure the *Stipa* grasses are not overgrazed. Protecting areas of drought-tolerant species such as bluebush (*Maireana sedifolia*) and bindyi (*Sclerolaena spp.*) close to warrens as refuge areas would help, because wombats have been observed to browse these species during extended droughts (St. John and Saunders 1989).

Ensuring suitable habitat and compatible land uses exist in the south-eastern corner of the Nullarbor wombat range in Yalata IPA (and also in Yellabinna Regional Reserve and Boondina Conservation Park) will be necessary to allow migration as the northern range becomes hotter and dryer. This may conflict with land uses on the southern boundary of Yellabinna Regional Reserve and Yalata IPA (primarily grazing modified pastures with some cereal cropping), and may conflict with stated intentions to re-start pastoral operations in the SE corner of Yalata IPA (i.e. in Colona and Pintumba). Another option could be to look at the possibility of turning the land on the eastern edge of Yalata IPA into a reserve, joining up Yellabinna, Boondina, Yumbarra, and Yalata IPA to allow for future wombat migration.

4.5.3 Malleefowl (*Leipoa ocellata)*

Figure 18 Mallee fowl recorded sightings in the AW NRM region (source: Atlas of Living Australia 2014)



Threat Rating: Rated Vulnerable (SA), Vulnerable (Australia wide) (NRM Plan 2011)

Ecology and climate interactions

Malleefowl are most commonly found in dense mulga scrub, dominated either by desert mulga (*Acacia minyura*) or old mallee (*Eucalyptus oxymitre or E. gammopyhlla*) (Figure 18). Malleefowl use the scrub for nesting but tend to forage in adjacent sparser spinifex country (Benshemesh 1997). The birds feed on herbs, fungi and acacia seed, often utilising seed expelled from ant nests when other seed sources have disappeared (Benshemesh 1997). Malleefowl prefer habitat that has not been burnt for at least 30 years, due to the need for a litter layer to build their nests (Churchill 2001).

Traditional patch burning of spinifex country surrounding mulga thickets where Malleefowl nests are found is likely to have protected habitat areas from wildfires, because the surrounding burnt spinifex country acted as a firebreak to naturally-induced fires (Benshemesh 1997). Patch burning also would have stimulated seed production in the spinifex country for use by the birds (Benshemesh 1997). However, Benshemesh (2007) argues that the main benefits of patch burning is the preservation of long-unburnt (60-80 year) mallee and its protection from wildfire, rather than the benefits of increased seed production in the areas where a fire has passed through.

Decline of traditional burning practices is likely to have caused a decline in Malleefowl numbers through habitat alteration and reduced food supply, although introduced predators (cats, foxes) are also likely to have played a fundamental role in their decline (Benshemesh 1997). While dingoes do prey on Malleefowl, they also play a role in reducing feral predator numbers (Benshemesh 1997). Baiting for foxes has also removed dingoes, leading to reduced predation pressure on foxes and cats, which are new predators of the Malleefowl.

Potential climate change impacts

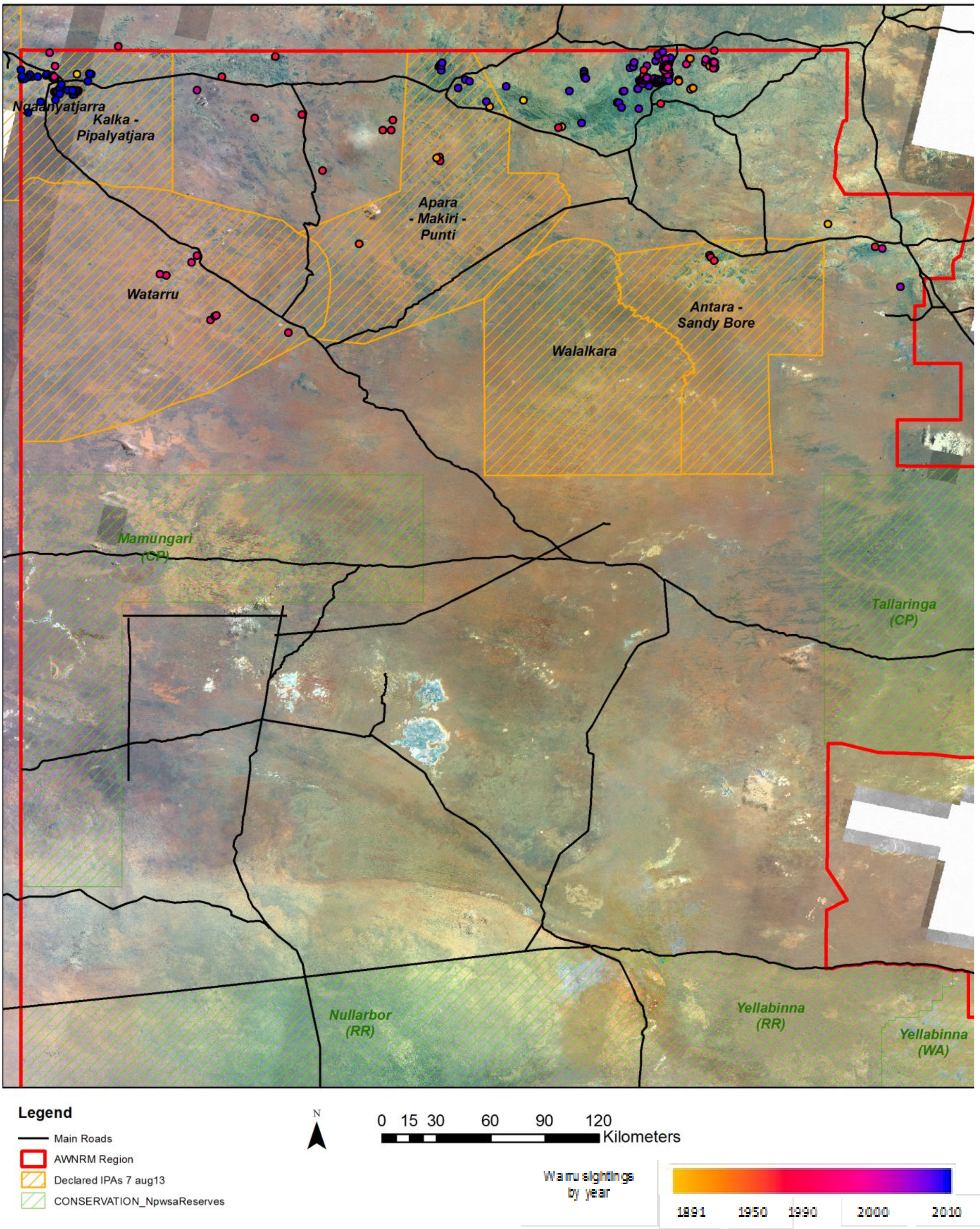
A drying climate, hotter temperatures, higher evapotranspiration rates and more intense rainfall events will increase the likelihood of large wildfires by promoting large dry fuel loads, which could threaten older Mallee habitat suitable for Malleefowl. The number of extreme fire weather days is also likely to increase, with fires starting earlier in the season and running later in the season.

Management implications

Patch burning is necessary to maintain a mosaic of fire-age vegetation classes and lessen the potential for large wildfires to destroy Malleefowl habitat (Ward 2008), by disturbing the sparse spinifex country which surrounds Mallee vegetation (Benshemesh 2007). In the absence of patch burning, (or perhaps in addition to these practices), it may be necessary to create fire tracks/breaks which fragment large areas of known Malleefowl habitat so that if a fire does burn, it won't burn large areas of Mallee scrub. Malleefowl would then be more likely to migrate to the unburnt 'islands' of remnant scrub, which would prevent populations being destroyed in a single large fire. Codes of practice for patch burning and creating fire breaks may need to be revised with communities to account for future hotter fires (i.e. make tracks wider, burn earlier in the season, etc.).

4.5.4 Warru (*Petrogale Lateralis* MacDonnell Ranges race, black-footed rock wallaby)

Figure 19 Warru recorded sightings in APY Lands, showing year of sighting (sources: Atlas of Living Australia 2014)



Threat Rating: Rare (SA NPWA 1972), Vulnerable (Nationally, EPBC Act)

Ecology and climate interactions

Warru require rocky outcrop areas as habitat (Figure 19). Such outcrops have a moderating effect on climate by providing cooler micro-climatic sites, as well as containing areas of concentrated water run-off and retention, higher plant diversity and productivity, and areas of shelter from fire and predators (Ruykys 2011). As such, they can be thought of as climatic and ecological refuges situated within broader, hotter landscapes. However, while Warru need rocky areas to survive, they can also disperse across plains to find new rocky habitat, as evidenced by the pre-European presence of rock wallabies across mainland Australia in suitable (and sometimes extremely remote) habitats (Ruykys 2011). However, Figure 19 suggests that most recent Warru sightings are constrained to localised areas of the main Tomkinson and Musgrave Ranges (Ward et al. 2011), compared with earlier sightings further south on the smaller rocky outcrops near Watarru and Mimili. Thus, they are already constrained to fringes of their potential distribution within the AW NRM region.

Warru eat a range of grasses, forbs, trees and shrubs, as well as seasonally available flowers, ferns and fruits (Ruykys 2011). Juvenile survival to adulthood is dependent on winter rainfall, although it is not currently known whether this is because it provides direct drinking water, or if it provides sufficient vegetation for consumption (Ruykys 2011). Warru competes with the euro (*Macropus robustus*) and rabbits for food, and the presence of rabbits also sustain larger predators such as cats and foxes, which in turn prey on Warru (Read and Ward 2011).

Potential climate change impacts

A warming climate may have negative impacts on the refuge potential of rocky outcrops, and as such is likely to reduce suitable habitat for Warru further. Temperature thresholds may be reached in these areas which may be above what Warru are able to tolerate, necessitating a further contraction in distribution to the higher and cooler parts of the Tomkinson and Musgrave Ranges. In addition, dispersal between rocky outcrops is likely to become more challenging and result in higher mortalities due to increased temperatures.

A predicted drying trend and warming temperatures during winter months (March-August) (CSIRO 2014) will have significant impacts on water availability for grass growth and drinking, which is likely to negatively impact juvenile Warru survival. Finally, climate change may make introduced species such as red foxes more competitive (see Section 4.8), which would increase the pressure on Warru through predation.

Management implications

The Tomkinson Ranges within Kalka-Pipalyatjara IPA, and Musgrave Ranges, particularly around Ernabella, represent key refuge areas for Warru in a hotter future climate, due to their high altitude providing cooler conditions and high habitat values. Given the difficulties any remaining Warru may have in migrating from the more marginal and patchy rocky outcrops in the south (e.g. in Watarru IPA) to the consolidated ranges of the north, it may be necessary to continue to assist this migration through trapping and relocation. Care also needs to be taken to ensure a diversity of potential reintroduction sites are created across the major ranges, in order to provide alternative sites in case localised reintroductions are not successful (DENR, 2010). A coordinated response with the northern

IPAs (e.g. Kalka-Pipalyatjara and Apara-Makiri-Punti) and the APY Land Management Warru program would help to ensure such requirements are met.

More research is needed to determine if juvenile Warru survival depends on winter rainfall to provide drinking water directly, or for stimulating grass production for feed. If it is the former case, the provision of alternative water points (e.g. shed tanks) excluded from feral predators could supplement natural rainfall in winter months. In the latter case, providing alternate feed sources may be required in dry winter years to prevent excess mortalities. Controlling rabbits could be another way to improve feed availability in the winter months. Managing predators (cats, foxes) by baiting or dingo reestablishment (Ruykys 2011) would help to reduce non-climatic pressures on Warru, and thus enhance their adaptive capacity to climate change.

Ensuring the rockholes in the ranges are cleaned regularly, and perhaps increasing catchment areas by using swales, could help to increase water availability, particularly in a more variable rainfall climate which will necessitate larger storages volumes to buffer this variability. On the areas surrounding rocky outcrops, furrows could be created to slow and capture run-off water from the outcrops and support grass growth, which would be accessible to Warru.

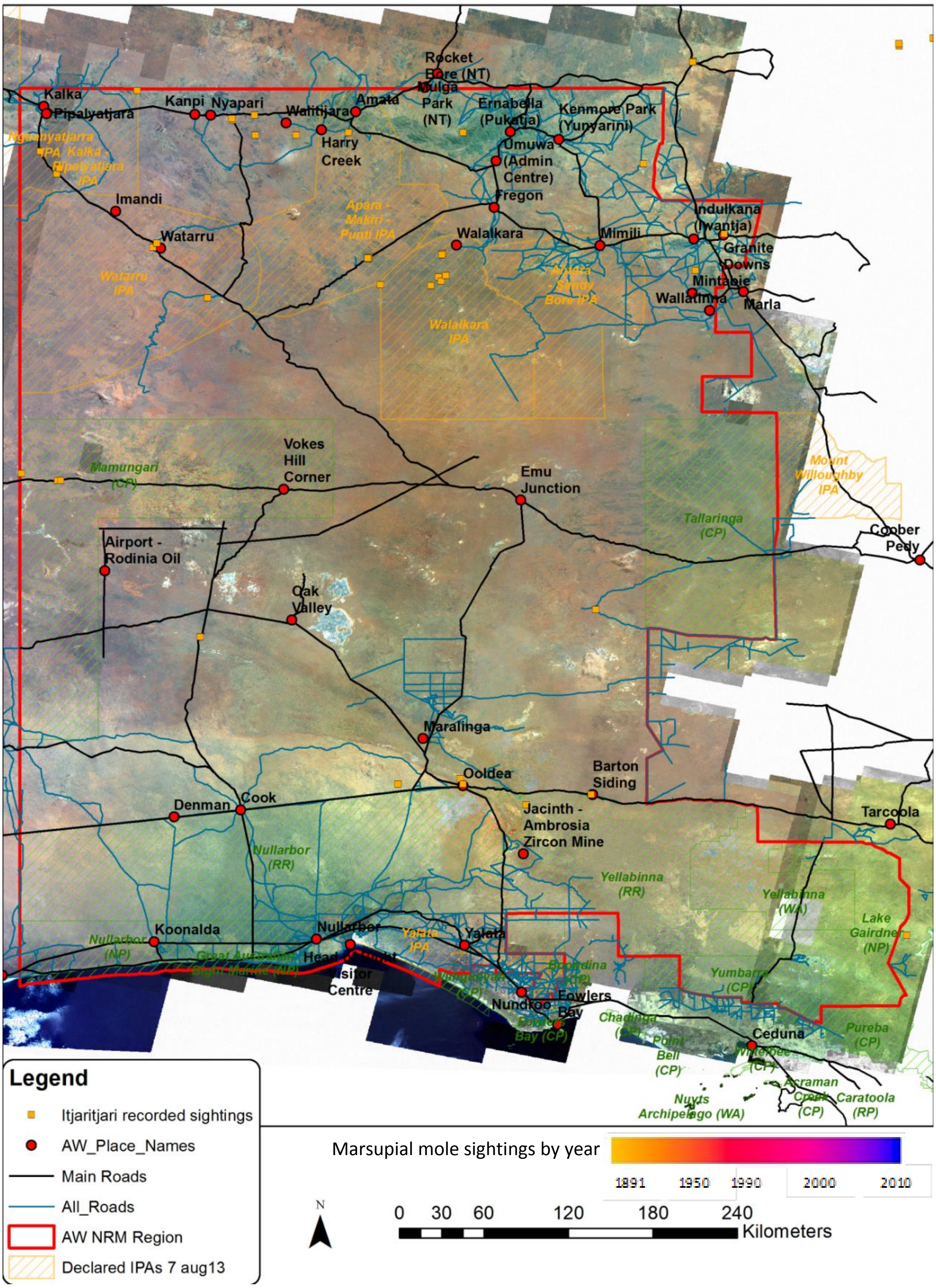
Finally, the reintroduction of Warru to establish new colonies, as expressed in several of the IPA management plans in the APY Lands, needs careful assessment to ensure that the chosen sites are able to provide adequate refuges in a warmer climate. This may rule out reintroducing Warru into highly isolated ranges or rocky outcrops (such as those found in Watarru IPA, Walalkara IPA and Antara-Sandy Bore IPA), and instead necessitate a greater management focus on the Tomkinson and Mann ranges around Kalka-Pipalyatjara, and the Musgrave ranges around Ernabella. A duplication of the *warru pintji* enclosure at Donald's Well NE of Ernabella (Muhic *et al.* 2012) at other key refuge sites (for example at Kalka-Pipalyatjara) may facilitate adaptation by reducing non-climatic pressures, and allow an enlarged breeding pool with which to re-populate open areas of the ranges.

Warru (black-footed rock wallaby)

4.5.5 Itjaritjari (Marsupial Mole, *Notoryctes typhlops*)

Distribution: Itjaritjari occurs in sand dunes and plains (Benshemesh 2004), and are presumed to be quite widely distributed in the AW NRM region based on recorded sightings (Figure 4 below) and observations of senior traditional owners (APY LM 2010).

Figure 20 Recorded sightings of Itjaritjari/Marsupial Mole, Notoryctes typhlops (Source: Atlas of Living Australia 2014)



Threat Status: Itjaritjari are listed as endangered under the EPBC Act.

Ecology and climate interactions

The ecology and biology of the Itjaritjari is largely unknown, as it is a relatively elusive animal which is rarely encountered due to its subterranean activity and distribution in extremely remote places (Figure 20) (Pavey et al. 2012). Because very little is currently known to science about its reproductive biology, life history, foraging behaviour or spatial ecology, it is very difficult to anticipate likely climate interactions with Itjaritjari behaviour. It is known that Itjaritjari are able to regulate their thermal environment by burrowing deeper or shallower depending on the weather (Benshemesh and Johnson 2003), which offers significant adaptive capacity to increasing temperatures as a result of climate change. Itjaritjari also appear more likely to surface after rain or in cooler seasons (Benshemesh 2004, Burbidge et al. 1988). As Burbidge et al. (1988, p18) document:

> *Most [aboriginal people] said that it could occasionally be found on the surface at any time of the year; a few said it was more common after rains or in the 'windy season' (September-October). The habit of emerging onto the surface for a few metres and then disappearing underground again was often mentioned. Eaten during hard times but generally regarded with feeling as a poor old man who cannot see. Alluded to in some areas as 'pensioner'.*

Pavey et al. (2012) looked at dietary preferences of Itjaritjari by analysing the digestive tract contents of museum specimens, and found that ants, beetles (mainly as larvae), moth larvae and to a lesser extent termites were the main prey consumed, although spiders, scorpions and plant material were also found. Ants, termites and beetle larvae were also the most abundant species sampled from soil cores taken on sand ridges in central Australia, where Itjaritjari are found. Apart from termites, which were actively avoided, all other prey categories appear to be eaten in proportion to their availability, suggesting that Itjaritjari is a generalist feeder, despite having specialist means of seeking out and capturing prey (Pavey et al. 2012). Thus, climatic and fire regimes are likely to influence Itjaritjari populations by controlling the availability of habitat for invertebrate prey species (Benshemesh 2004).

The main predators of Itjaritjari include foxes, and to a lesser extent, dingos and cats (Benshemesh 2004). Trampling by camels and cattle could also have an impact on suitable habitat by compacting soil and preventing burrowing (Benshemesh 2004).

Potential climate change impacts

Benshemesh (2004, p19) summarises the difficulty in estimating impacts of climate change on Itjaritjari, noting:

> *Current predictions of climate change for Australia (Pittock & Wratt 2001) provide considerable cause for concern and projected changes in rainfall and temperatures, and concomitant changes in biota, might threaten marsupial moles over their entire range. However, modelling the effects of climate change on populations is not likely to be instructive at this stage because little is known about the climatic responses of marsupial moles. Moreover, little can be inferred about climatic constraints from distribution as available records suggest that marsupial moles occupy most of the available sandy habitats and do not appear to be constrained by climate as much as by substrate. Thus, there is little basis from which to construct meaningful models at this stage.*

Itjaritjari appear to be more adapted to changes in temperature due to their ability to burrow to different depths. Changes in rainfall and fire regimes, along with grazing pressures from introduced herbivores, and increased predation from red foxes (see Section 4.8) could have more significant impacts on their populations. More variable rainfall, with longer droughts in-between larger rains, may reduce spinifex and other grass cover of sand dunes. While more intense extreme rain may actually promote increased grass and shrub growth in the short term, subsequent fires will become hotter and more widespread due to increased dry biomass, increasing temperatures, and the invasion of Buffel grass, potentially leading to widespread loss of native grasses and shrubs. A decline in such species will reduce habitat for invertebrates, and reduce prey availability for Itjaritjari. Increasing grazing pressure from feral camels, which are relatively well adapted to future climate change, may also reduce habitat availability for Itjaritjari prey species, trample vegetation and compact soils and reduce Itjaritjari's ability to burrow.

Management implications

Due to the lack of knowledge about Itjaritjari, monitoring should form a core part of climate change adaptation. As noted by Benshemesh (2004), their widespread distribution across the Northern Territory, Western Australia and South Australia suggests they are well adapted to a range of different arid and semi-arid climates. In addition, their ability to burrow to different depths to regulate temperatures suggests they will be able to adapt to warmer temperatures. One weak point may be in Itjaritjari's food preferences, as climate change may have significant impacts on small insects, rather than directly impacting Itjaritjari itself. Thus monitoring Itjaritjari's preferred prey (i.e. ants and beetles) in terms of seasonal availability, distribution and ecology will be useful to determine seasonal and longer-term climate change impacts on these species.

Other management practices likely to reduce non-climate pressure on Itjaritjari are reducing feral camel numbers and managing fire to promote small, cooler burns rather than large wildfires. In areas where Itjaritjari are known to be in abundance, limiting the amount of hard surfaces from roads, railways and pipeline trenches will help to allow dispersal and prevent populations from becoming genetically isolated (Benshemesh 2004). It will also allow longer-term migration if changing rainfall patterns fundamentally change the prey species available.

Itjaritjari/Marsupial Mole (Photo Credit: Australian Geographic and Uluru-KataTjuta National Park)

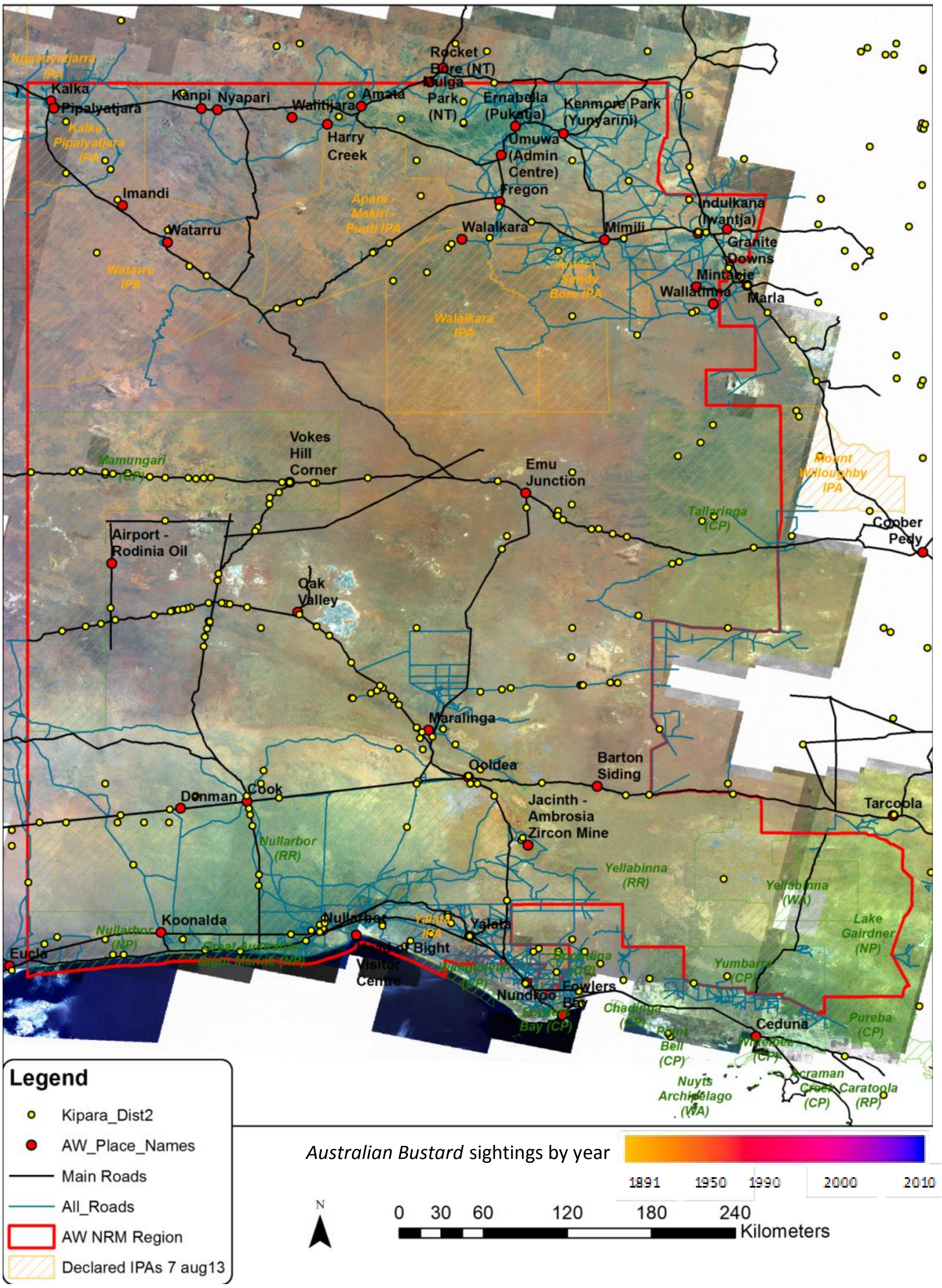
4.5.6 *Kipara* (Australian Bustard, *Ardeotis australis*)

<u>Threat Rating:</u> Threatened (SA)

<u>Distribution</u>

The Australian Bustard is presumed to be widespread over the AW NRM region when conditions are favourable (Figure 6).

Figure 21 Australian Bustard recorded sightings in the AW NRM region (source: Atlas of Living Australia 2014)



Ecology and climate interactions

The Australian Bustard is a large migratory bird which follows fires, rainfall and food resources (such as grasshopper and mice plagues following rain) across semi-arid central and monsoonal northern Australia (Figure 21)(Ziembicki 2006). While rainfall patterns can lead to longer inter-regional migrations, detection of and travel to fires necessarily occurs at smaller intra-regional scales (Ziembicki and Woinarski 2007). The Australian Bustard is considered to be migratory in the monsoonal North of Australia where there is a reliable seasonal rainfall pattern, however in central arid and semi-arid regions characterised by extreme rainfall variability, it is considered to display nomadic or irruptive movement patterns in response to above average rainfall (Ziembicki and Woinarski 2007). Recent rains, as well as fires, can provide a localised abundance of food for the Australian Bustard, which has an omnivorous diet consisting of a range of seeds, fruits, vegetation, insects and small vertebrates (Ziembicki 2006). Although rainfall is necessary to initiate the growth of these resources, the Australian Bustard may favour later stages of drying/senescing grasslands where these food resources are often more abundant, compared with the lush green growth immediately following rains (Ziembicki and Woinarski 2007).

The Australian Bustard is considered to be threatened by a range of factors including: alteration to grasslands through overgrazing and changed fire regimes; predation by introduced foxes and cats; hunting; loss, fragmentation and degradation of open grassy woodland habitat (e.g. through woody weed infestation); and secondary poisoning from rabbit baiting (Government of NSW 2014, Ziembicki, 2006). Yet as Ziembicki (2006) notes, there is little data on the relative effects of those threats on population numbers.

Potential climate change impacts

In a hotter, more variable rainfall climate, many of the threats to the Australian Bustard are likely to be exacerbated, including: larger wildfires and further habitat fragmentation (due to increased temperatures, longer dry periods and increased Buffel grass spread); increased overgrazing due to longer drought periods; and increased predation and hunting due to resource scarcity. Given Bustards are likely to only travel inter-regionally in response to fire events, this may reduce the availability of food options within a region because large areas of vegetation would be in the same post-fire seral stage after a large wildfire. Larger rainfall events with longer drought periods between these events may increase the amount of migration in order to find areas of recent rainfall, which may negatively impact upon population numbers. However, if rainfall is also more spatially variable, this may provide more localised resources, depending on the threshold levels of rain that are necessary to initiate a growth response in food resources.

Management implications

While there are many existing threatening processes and these are likely to increase with future climate change, the Australian Bustard can be considered relatively resilient to climate change due to its migratory nature, compared with other species which are less mobile. This allows it to follow increasingly variable rainfall or to reside for longer periods in places with more consistent rainfall patterns (e.g. the Monsoonal North) if necessary. Despite this resilience, managing fire regimes will be still be important to ensure a patchwork mix of different fire seral stages is present at the regional scale. Ziembicki (2006) notes the importance of avoiding late dry-season fires which coincide with the bird's breeding season in the Northern Territory, and such a risk may also be applicable for the northern parts of the AW NRM region. By constraining burning to the cooler parts of the year, burning during the breeding season would be avoided while also reducing the risk of large wildfires.

Controlling existing threats such as predation, hunting and overgrazing, particularly in key breeding habitats and at key times (Ziembicki 2006) will also be important adaptation strategies to reduce non-climatic pressures. Ziembicki and Woinarski (2007) highlight the potential for predictive or pre-emptive conservation management, by targeting preferred habitats for management activities (e.g. predator control, hunting moratoria, preventative burning) at particular times and places (e.g. after rainfall, during breeding seasons, at important refugia during drought) in mobile or shifting conservation zones, rather than utilising static conservation reserves which fail to reflect the dynamic and highly mobile nature of this and other dispersive species. This highlights the need for widespread and ongoing monitoring of local conditions in order to track local events and respond accordingly. These management activities, which are concentrated both in space and time in response to highly localised weather conditions, are likely to have the most benefit in an increasingly variable climate.

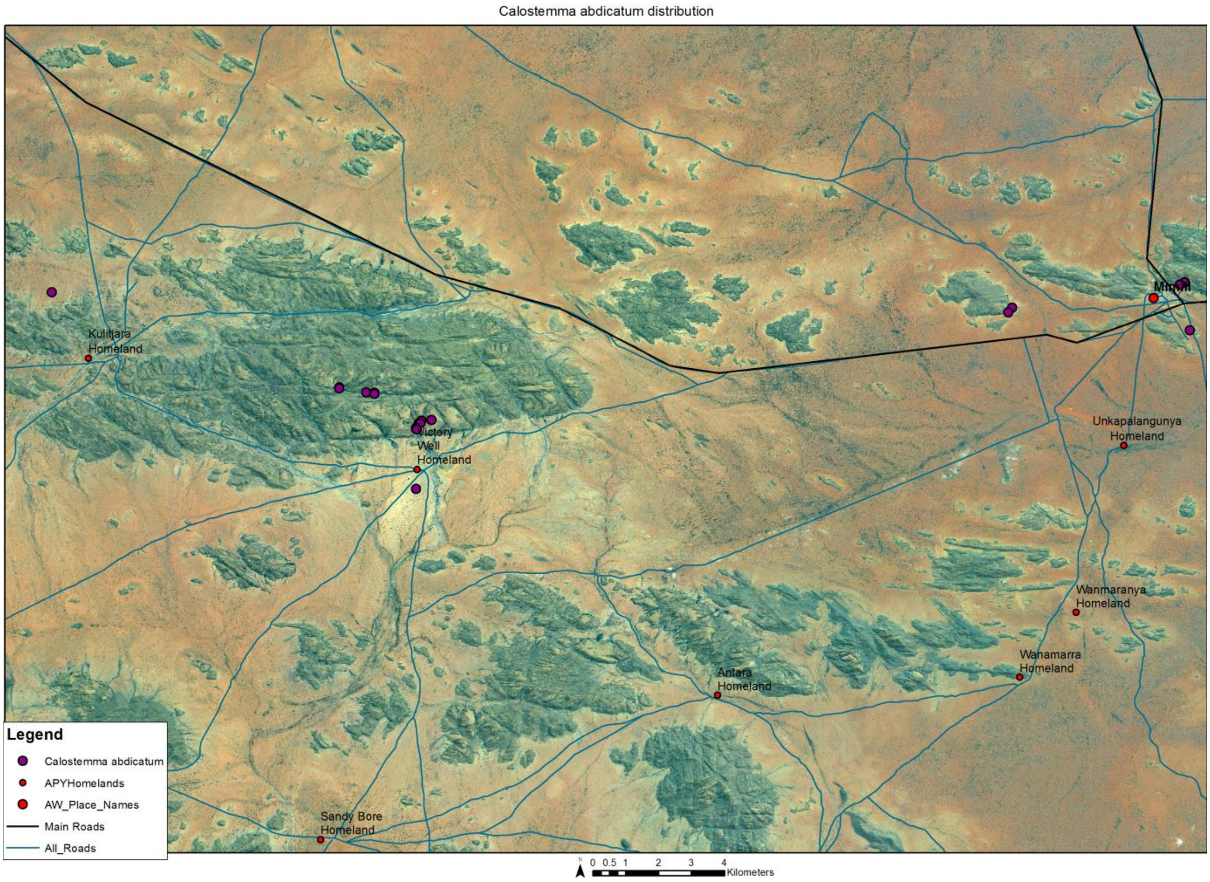
Australian Bustard

4.5.7 Everard Ranges Garland Lily (*Calostemma abdicatum*)

Distribution and threat status

The Everard Ranges Garland Lily, *Calostemma abdicatum*, was collected in 2000 as part of the Biological Survey of the APY Lands (Figure 18) (Lang 2008). While other specimens of this plant had been collected in the Everard Ranges region prior to 2000, they were thought to be examples of either *C. purpureum* R.Br. endemic to the south-eastern coast of Australia, or *C. luteum* Sims from the north-eastern coastal regions (Lang 2008). Lang (2008) describes the newly recognised species, noting that it likely to be endemic to the Everard Ranges, and as such, is considered Rare under the IUCN convention.

Figure 22 Observations of the Everard Ranges Garland Lily, Calostemma abdicatum *in the northern AW NRM region (Source: ALA 2014)*



Ecology and climate interactions

C. abdicatum requires shaded, moist and loose alluvial soils found in creek beds, rocky gullies and the southern slopes of steep hillsides in depressions where soil accumulates. The Everard Ranges provide a unique habitat for this plant, as the steep-sided granite mounds allow concentration of runoff which supports a shady over-storey and adequate soil moisture, as well as providing nutrients from the weathering of the granite rock (Lang 2008). Its fruit are round and buoyant, allowing seeds to disperse by either rolling downslope or by being carried by water (Lang 2008).

Potential climate change impacts

The restriction of the Everard Ranges Garland Lily to the Everard Ranges increases its vulnerability to climate change due to its limited distribution and isolation from other potentially suitable habitats in the larger Musgrave and Mann Ranges. While the Everard Ranges represent a refuge habitat compared to the surrounding plains, the dependence of *C. abdicatum* on moist, shaded and nutrient-rich sites means there is little scope for adaptation via retreat to better-suited habitats as these are likely to be already all exploited. The ability to persist as dormant bulbs may offer an adaptive advantage, particularly if rainfall becomes more variable, with larger downpours and longer times between rainfall events. Dispersal of seed may actually be enhanced if rainfall becomes more intense, however suitable habitat is likely to contract due to hotter temperatures and higher evaporation rates leading to reduced soil water storage.

Management implications

Relocating seed to similar habitats in the larger Mann and Musgrave ranges could be an important adaptation response to offer some redundancy should the Everard Ranges population be threatened by climate change or other threats. However care would need to be taken to ensure that *C. abdicatum* did not become invasive in these habitats and displace other important plant species. At a local scale, manually moving seed upslope to suitable sites which are not already colonised by *C. abdicatum* could be a way of increasing potential habitat area, given that the seed naturally tends to only fall or be washed downslope. Further research is needed to determine the ecological relationships of the species (e.g. pests and predator relationships) before other management recommendations can be made.

While threats to species are often specific to the species itself or its ecological relationships, potential threats to the Lily, and other species, will interact strongly with other climate change impacts on the environmental conditions in the AW NRM region.

4.6 Water management

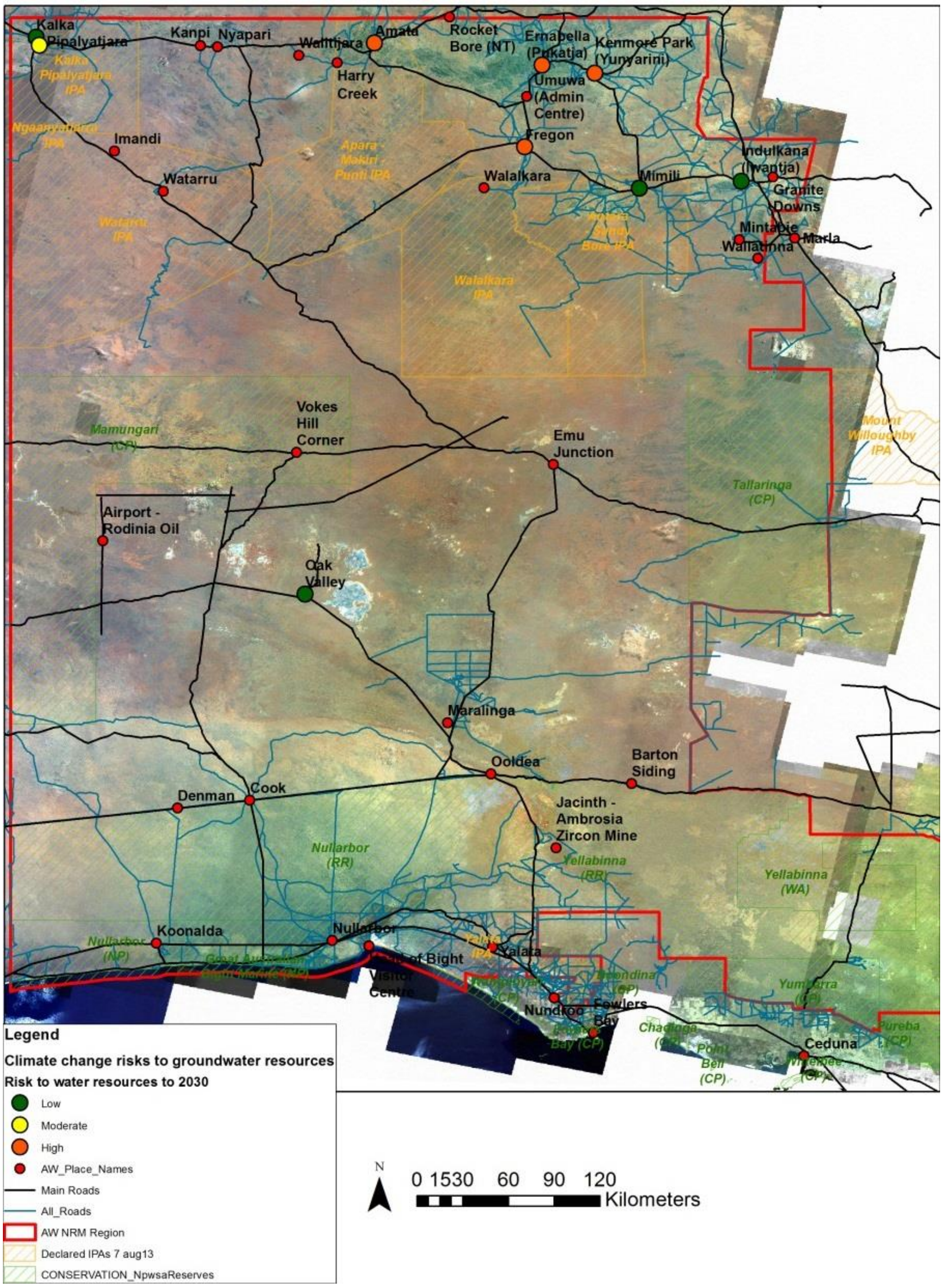
One of the most significant environmental issues raised in all community workshops in the APY Lands was flooding. Floods impact directly on houses and other infrastructure, as well as on human mobility and access to essential items such as food, fuel and medicines. For example at Ernabella (2014):

> *During the flood in 2011 the road behind the store that crosses to the school was washed away. The bitumen was washed away and other dirt roads further south were washed away too, on the road to Umuwa. People were sitting in their homelands for weeks and couldn't make it back to the community.*

There were also concerns raised about water access for pastoral operations, with some respondents noting bore wells used for stock water were drying up in their area. Rockhole management was another cause of concern, particularly in regards to the impacts that feral animals are having on rockholes by drinking all the water or their carcasses fouling the water.

Climate change will exacerbate existing water issues in the region, through an increased likelihood of large floods, longer dry periods between rains, and increased demands on water resources by people and ecosystems in the region due to hotter temperatures. By 2030, Ernabella, Fregon, Amata and Kenmore Park water resources have been identified at high risk as a result of climate change due to their moderate to strong groundwater responses to contemporary rainfall (Alcoe *et al.* 2012 – see Figure 23). By 2050, water resources at Ernabella, Fregon and Kenmore Park are projected to be at very high risk due to climate change, with Oak Valley and Pipalyatjara increasing to high risk also (Alcoe *et al.* 2012). Ernabella is at further risk due to declining groundwater levels and increased demand. Yalata is at low risk due to climate change, but has experienced declining groundwater levels since 2000 (Alcoe *et al.* 2012).

Figure 23 Projected risk to capacity of community water resources by 2030 (Data source: Alcoe et al. 2012)



More generally, groundwater recharge in the Musgrave Ranges depends on large infrequent rainfalls of greater than 80mm in a month, or enough rain to generate overland runoff and subsequent concentration in valleys and river channels and infiltration to sedimentary aquifers (Leaney et al. 2013, Kretschmer and Wolling 2014). This suggests that while annual rainfall might decline in the APY Lands, any increase in large episodic downpours in summer and autumn months associated with an increased Australian monsoon may counterintuitively increase groundwater recharge in some parts of the region.

Adapting to changed water availability will largely be a local issue, due to the complexity of local catchments and groundwater resources. However, across the region, monitoring should be undertaken of all community water usage and bore withdrawal rates. While water records have been kept for some communities (Willis et al. 2004), there appear to be opportunities for improved data collection and management. In the short term, priority for monitoring should be given to those communities with groundwater resources deemed at highest risk due to climate change (e.g. Amata, Ernabella, Kenmore Park and Fregon). However water resource monitoring should ideally be done at every community in the medium-term. The community water data could be collated and presented in an accessible form (e.g. on AW NRM's website) to determine trends in water use and water resources and allow comparisons between communities by comparing water use per capita; trends in water use in response to heatwaves; and trends in bore water resources over time in response to changes in demand and changes in recharge. This information would also be invaluable for pre-empting when water resources are likely to become scarce, and to allow time for adaptive responses. In association with monitoring, a target benchmark could be set across the AW NRM region for reduced water consumption: to reduce the dependence on water resources which are likely to get much more unpredictable and unreliable in the future. At present, household water usage information is not easily available for users in communities, which prevents any feedback to regulate use. Sharing information about water usage rates across the communities as part of a community water saving campaign might also encourage friendly competition between communities.

There are several general principles for managing water resources in a changing climate. These include:

- increasing the storage capacity of all water sources (e.g. rainwater tanks, rockholes) to catch and store larger downpours and to supply water over longer dry periods (for example by cleaning rockholes regularly)
- reducing the demand for water (e.g. by using water efficient devices, making sure homes are well insulated and shaded, and promoting water efficient behaviour)
- reducing evaporation of water
- reducing other pressures on water resources (such as feral animals).

Reinstating traditional practices such as expanding the catchment areas of rockholes by creating diversion drains upslope, or covering rockholes with branches or rocks to reduce evaporation and prevent feral animal access could help to maintain these important water sources for both people and ecosystems in a hotter more variable rainfall climate (Willis et al. 2009).

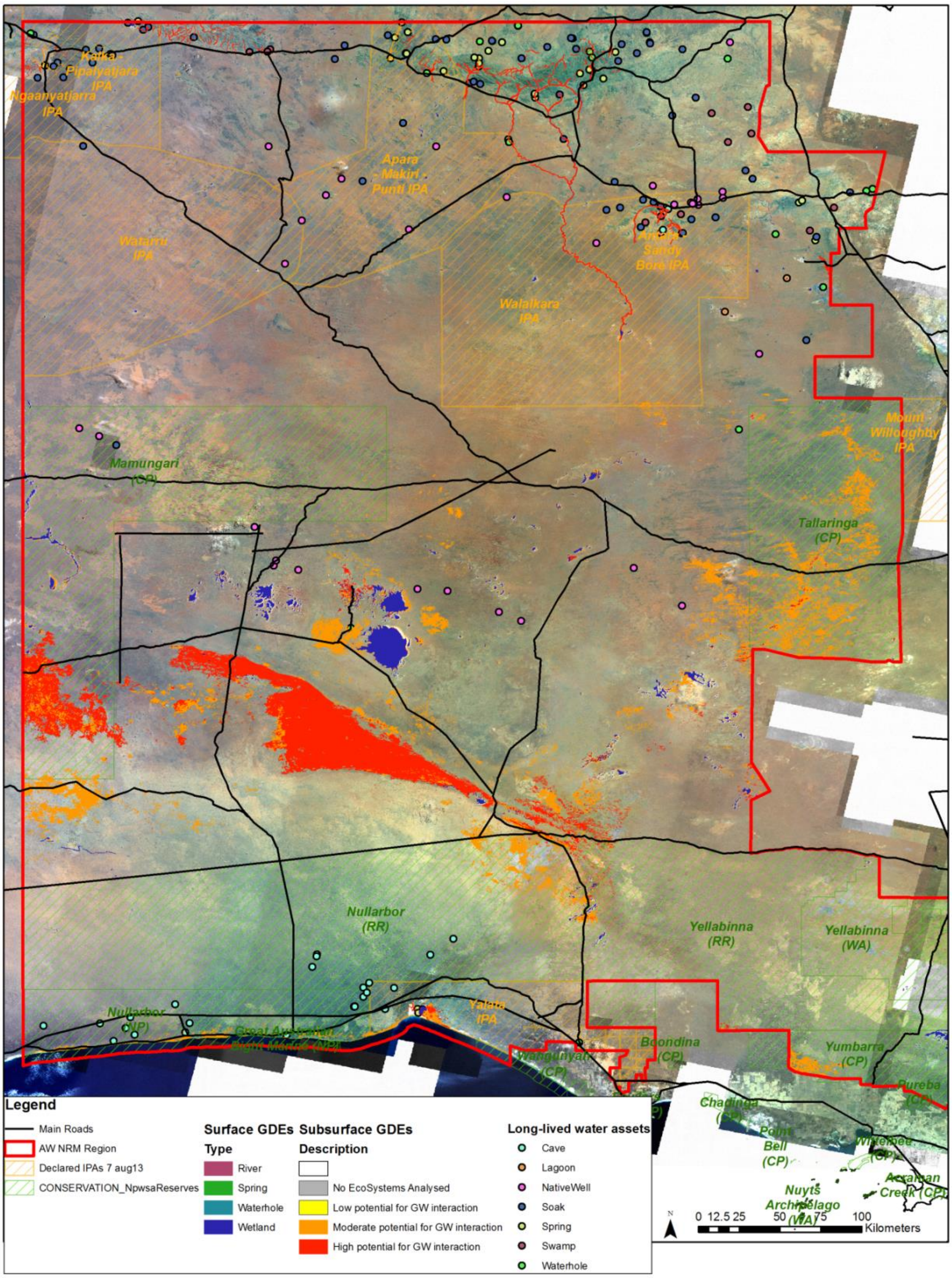
Determining the most important surface waters on which to focus management activities will involve both cultural and ecological values. For example, ephemeral rockholes, despite only having medium prioritisation for protection based on ecological values (Davis 2014), are typically highly culturally important. As in previous reports (e.g. Bardsley and Wiseman 2012a), and where there is conflict between the values of water resources, we would argue in favour of a valuation that prioritises cultural elements. Unless Anangu are supportive of adaptation activities for rockholes and other surface water sources, such activities are unlikely to be sustainable in the long term. Focussing on cultural priorities also sidesteps the issue that the majority of water assets in the AW NRM region have not been scientifically studied in terms of understanding their status (i.e. as evolutionary or ecological refugia) or geomorphic attributes.

Figure 24 below indicates water assets that are likely to be long-lived, and hence potentially important animal refugia, and also surface- and subsurface-groundwater dependant ecosystems. Key potential groundwater dependant ecosystems include areas north of the Nullarbor Plain which show medium to high potential for groundwater interaction; mulga woodland areas within Tallaringa Conservation Park; and the major drainage channel of Officer Creek running from the ranges around Ernabella, through Fregon and forming the shared borders of Walakara and Antara-Sandy Bore IPAs (see section 4.10 Biodiversity and Carbon). Potential long-lived water assets include the cave systems of the Nullarbor Plain, traditional wells surrounding Oak Valley in the central region of the AW NRM region, and a large range of water assets clustered around the Mann, Musgrave and Everard Ranges of the APY Lands.

While the data presented in Figure 24 provides a useful start, much more information is needed about the cultural and ecological values of these water assets and ecosystems. Focussed workshops with Anangu, water scientists and anthropologists on surface water and groundwater dependent ecosystem protection could develop a useful list of prioritised assets, adaptation activities and responsibilities for undertaking such work.

Davey's Bore, Policeman's Well

Figure 24 Water assets that are likely to be long-lived, and surface- and subsurface- groundwater dependent ecosystems (GDEs) in the AW NRM region (ecosystems with low potential for groundwater interaction have been omitted from this data. Sources: water assets – AW NRM, GDEs – BOM 2014c)



To support adaptation at a household scale, downpipes could be redirected from house and office roofs into swales/pits where trees are grown, to reduce erosion, run-off and flood risk from projected larger rain events, while providing shade and reducing heat stress and air-conditioner use (Last 2002). This redirection of stormwater would also have potential benefits depending on the vegetation being propagated, such as food production and habitat value, and could reduce emissions from air-conditioner use. Plumbing rainwater tanks into houses also effectively increases the value of the tanks by ensuring that they are always being used, and thus ensuring they will have some spare storage capacity when rain falls. Being low-cost and relatively simple in terms of materials/tools required, such a scheme could be constructed locally and provide local training and employment.

At a larger community scale, diversion of run-off from rocky areas, drainage lines and roads to series of swales could reduce flood risk to community infrastructure by slowing, spreading and sinking the water and enhancing vegetation growth (see Last 2002 for examples in Kalka and Pipalyatjara).

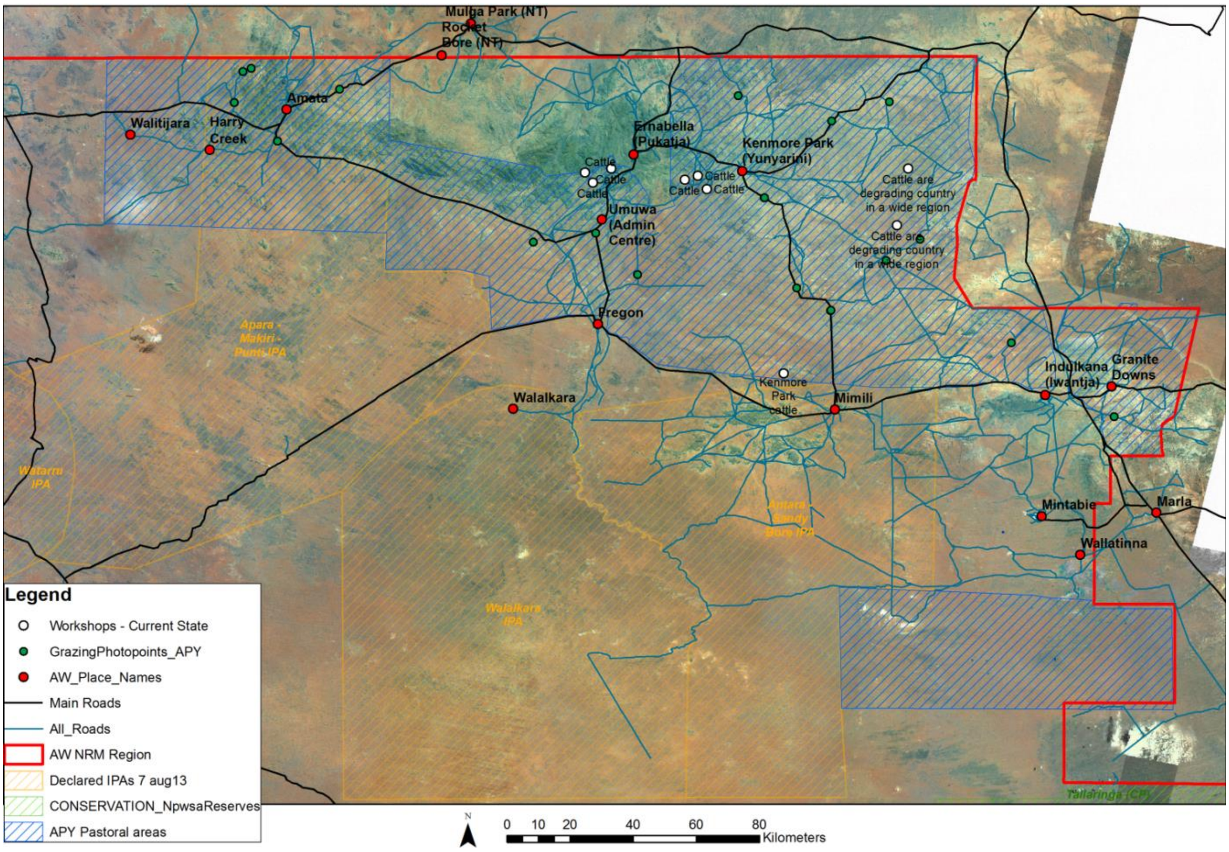
4.7 Grazing

Grazing practices will also need to adapt to a changing climate. Cattle production is presently confined to the north-eastern APY Lands in the north of the AW NRM region (Figure 25), in some of the most variable rainfall areas in Australia (BoM 2014b). The grazing of cattle here is a contentious issue, with some workshop respondents noting the detrimental impacts cattle have had on important bushfood species, both mai and kuka:

> *The cattle don't belong to us - we would like them out now. The cattle bring more flies, they bring more buffel and they go over the dreaming country. I don't get any money from the grazing of my country, so I want them out of my homeland. The cattle are eating grass and destroying everything. The owner of the cattle didn't pay us. Also because the cattle are there we are not allowed to burn the country to get rid of the grass – the cattle want the grass.*

Figure 25 also indicates where cattle were perceived to be a problem during workshop discussions, as well as the areas designated for pastoral production in the APY Lands, and the existing grazing photo-points established to monitor pasture and land condition. While cattle were perceived by some respondents as a problem, for traditional owners who run cattle or lease land to pastoral operations, grazing provides a regular source of income and long-term employment opportunities for the wider community. There is a strong desire to develop a sustainable beef industry in the APY Lands, which provides income and employment, particularly for young people, but which also looks after the health of the country (APY Pastoral and AW NRM 2013).

Figure 25 Pastoral regions in the APY Lands (blue shaded areas), points where community workshops identified problems with cattle damaging country (white circles), and existing photo-points for monitoring pasture condition (green circles).



Hotter temperatures, heatwaves, more irregular rainfall, with more intense storms and longer droughts in between, will all negatively impact on grazing opportunities in the AW NRM region. Those impacts will result directly from impacts such as heat stress, and indirectly via declining pasture quality and added pressure on water resources (Bastin *et al.* 2014). Other impacts could include increased risk of fire and flood damage to infrastructure, and growth of woody unpalatable species (Bardsley and Wiseman 2012a, Bastin *et al.* 2014). Yet climate change also provides an opportunity to better manage pastoral operations both for improved land condition and resilience to high climate variability.

At a sub-regional scale, regular monitoring of existing grazing photo-points could be prioritised. Simultaneously involving community members in monitoring would generate transparency about the assessment process regarding the condition of pastoral lands, which may help to reconcile negative perceptions of cattle impacts. Tying monitoring of pasture condition, either using photo-points or remote sensing, or a combination of both, to enforced destocking policies when conditions reach a certain lower threshold could be seen as crucial to ensure that pastures are not completely degraded, and are able to respond to even small rainfall events (Bastin 2014c, Bastin et al. 2014). Locating new photo-points in areas that are used for bushfoods, or conducting bushfood abundance/quality surveys in concert with pastoral monitoring, will help to determine what effect grazing is having on highly valued plant and animal foods. Similarly, long-term trials should be established to determine the impacts of grazing on Buffel grass, comparing it to areas that have no grazing, to establish whether grazing has positive effect on controlling Buffel grass over the medium-term.

Some areas could be targeted for monitoring and management of specific cultural values, such as the woodlands to the north east of Ernabella (see Section 4.4), to ensure bushfoods are not destroyed by a combination of cattle grazing and other large herbivore damage (e.g. from camels, donkeys and horses).

At a property/business scale, there are a number of adaptive strategies available for good animal husbandry and grazing practices. Many of these actions are considered best-practice regardless of future climate change (AWI 2009), but climate change provides yet another reason why they should be adopted. Potential activities (developed from AWI 2009, Bastin *et al.* 2014, Norton and Reid 2013, Purvis 1986, and Walsh 2009) could include:

- Keeping an eye on longer-term seasonal forecasts, using information such as BoM and CSIRO's Predictive Ocean Atmosphere Model for Australia (http://poama.bom.gov.au/) to plan and prepare for the coming seasons
- Be prepared for drought – assume the next year will be drought and stock for the worst years, not the best, in order to prevent overgrazing and provide a buffer of surplus vegetation for use in dry times. Perennial vegetation that is retained can respond quickly to rainfall and grow new leaves, but if the land is overgrazed it will take much longer to respond (if it responds at all). A cover of perennial vegetation also helps to prevent wind and water erosion of topsoil, which is likely to increase due to more intense storms and flooding
- Accompany any reduction in stock numbers by targeting niche markets and product brand differentiation to get a better price per head of cattle
- Shut off waters when paddocks are not in use to reduce grazing pressure from other herbivores (e.g. camels, donkeys and kangaroos)
- Create ponding banks where there is erosion potential to capture larger rainfall events, reduce erosion and grow productive perennial grasses
- Use smaller paddocks, more water points and higher rotations with long rest periods to reduce the time spent in each paddock and the time stock take to reach water, thus reducing the potential for overgrazing and declines in stock health due to long distances to water (i.e. following cell or rotational grazing practices)
- Breed cattle as part of operations and select for resilient stock that are adapted to local conditions
- Manage fire (e.g. firebreaks, preventative burns, controlled grazing) to reduce the risk of large destructive wildfires and to control woody weeds
- Ensure shaded areas are available for stock to rest during heat waves to reduce stress
- Shade stock waters to reduce evaporation rates which are projected to increase
- Limit stock access to creeklines to reduce damage on high-carbon assets

A more comprehensive list of adaptation strategies are suggested in the Appendix of Bastin et al. 2014.

4.8 Feral / invasive animals

Feral animals, particularly camels, were consistently raised as an important environmental issue in community workshops in the APY Lands. Feral camels destroy important bush food plants, empty rockholes of water and foul water sources. They also damage community infrastructure such as rainwater tanks during dry years looking for water.

> *Camels are a problem; they are dying in water holes, eating Quandong and coming into communities. Yards are being built to get them off, and there is more culling when in the past there was very little. Certain areas are too remote and they are shooting them now. They are trucking horses and donkeys out now as well. Camel management has come a long way but there needs to be a lot more done. They have a massive impact on surface water resources.*

In Yalata in the south, while camels are present, they are not such an issue within the IPA compared with further north. Other feral/invasive animals, including foxes, cats, horses and donkeys are all clearly species of concern within the AW NRM region, and have significant negative impacts on biodiversity and ecosystem function (AW NRM Plan 2011). Table 11 outlines the major invasive animals within the central rangelands that are applicable to the AW NRM region, as well as projections for future abundance and distribution with climate change.

Table 11 Predicted changes in abundance and distribution of invasive animals with future climate change (Source: Pavey and Bastin 2014)

SPECIES	ABUNDANCE	DISTRIBUTION	COMMENTS
Red fox	Moderate increase	Stable	Increased dingo abundance may reduce fox abundance
Feral domestic cat	Moderate decrease	Decrease	
One-humped camel	Stable	Stable	
Feral horse	Stable	Stable	
Feral donkey	Stable	Stable	
Feral goat	Moderate decrease	Moderate decrease	Increased dingo abundance may reduce goat abundance
European rabbit	Decrease	Decrease	Influenced by predator abundance and continuing effective forms of biological control

Pavey and Bastin (2014) note that dingoes/wild dogs, which are considered invasive in the pastoral areas of the rangelands, are projected to increase in both distribution and abundance with future climate change. This increase is likely to have important biodiversity benefits for the AW NRM region due to the control dingoes exert on native herbivores (especially kangaroos), introduced herbivores and the red fox. This control has been shown in turn to result in increased populations of small native mammals, birds and reptiles, leading to positive ecosystem outcomes overall (Pavey and Bastin 2014). This has been observed in the south of the AW NRM region around Yalata, with one IPA ranger noting:

Dingoes keep the wombat, cat and fox numbers down and there are more small native species. When we had a big camel cull dingoes would have had high survival rates as they feed on the carcasses. There are not so many visible in the mallee but there are lots around and especially when there dry conditions they eat a lot.

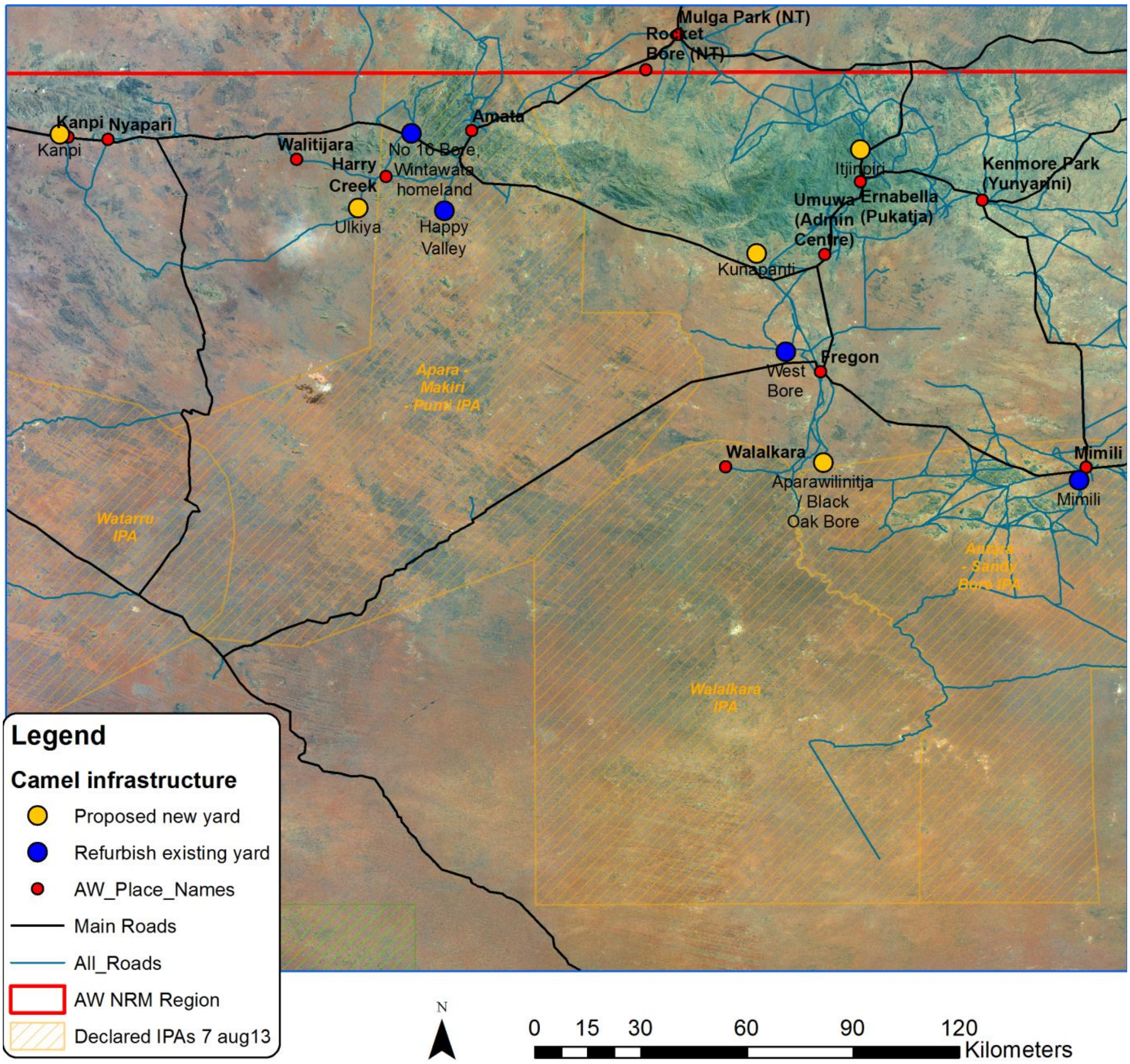
Feral camels, donkeys and horses will all require continued, systematic control in a hotter, drier climate, as all of these species are adapted to these conditions and are projected to have stable abundance and distribution with climate change. In contrast, cats, goats and rabbits are projected to decrease in abundance and distribution, either through direct climate effects (i.e. increasing temperatures), or indirect effects (e.g. increased dingo abundance may reduce goat abundance). The red fox is projected to moderately increase with future climate change, however as noted above, if dingo populations increase this may reduce their abundance to some extent. Thus feral herbivores and the red fox present the highest priority for management in the context of impacts from climate change.

Management activities to control feral herbivores and the red fox are essentially “do more of the same” for climate change adaptation (Pavey and Bastin 2014). For red foxes, this includes 1080 baiting, and allowing dingo breeding to control fox abundance. For feral herbivores, this includes mustering, aerial shooting to waste, and restricting access to stock waters and other water sources. In the south at Yalata, control is mainly by shooting to waste, as mustering is perceived as too costly, as well as risky due to safety and animal welfare concerns. However in the north of the region, communities have expressed interest in managing camels by mustering and selling them (AW NRM 2014). This interest was reflected in the community workshops, with one respondent saying:

We need a bore for camels out of town. We are keen to work with camels, we want a bore and yards to make our own money. The camels have been damaging waterholes for a long time – these sites are important to women.

AW NRM has recently developed feral herbivore infrastructure plans to increase the ability of communities to muster camels and other large feral herbivores (i.e. donkey and horses) (AW NRM 2014, see Figure 26). Along with direct impacts on the abundance and distribution of feral herbivores, there is also a concern that rising temperatures will put additional stress on feral herbivores mustered for removal. Hotter temperatures, longer and hotter heatwaves, and more variable rainfall will all negatively impact on the welfare of mustered stock. These impacts will necessitate greater provision of water and shade, and ideally shorten holding times before animals are removed. The construction of a local meat processing plant may help to alleviate heat-related stress on animals, improve the profitability of the mustering enterprise, provide local employment, and provide a buffer (using cold storage) against heatwaves or floods preventing truck access and leading to declines in animal condition. However, such a venture needs a region-wide coordinated approach between land managers and traditional owners, TAFE SA and other training providers, APY, AW NRM, and the State Feral Camel Management Project (PIRSA / DEWNR), given the history of past unsuccessful attempts to establish such a facility. The construction of additional camel mustering yards (Figure 26) will likely make the operation of such a plant more viable due to increased and more regular mustering activities.

Figure 26 Existing and proposed feral camel holding yards in the APY Lands (Data source: AW NRM 2014)

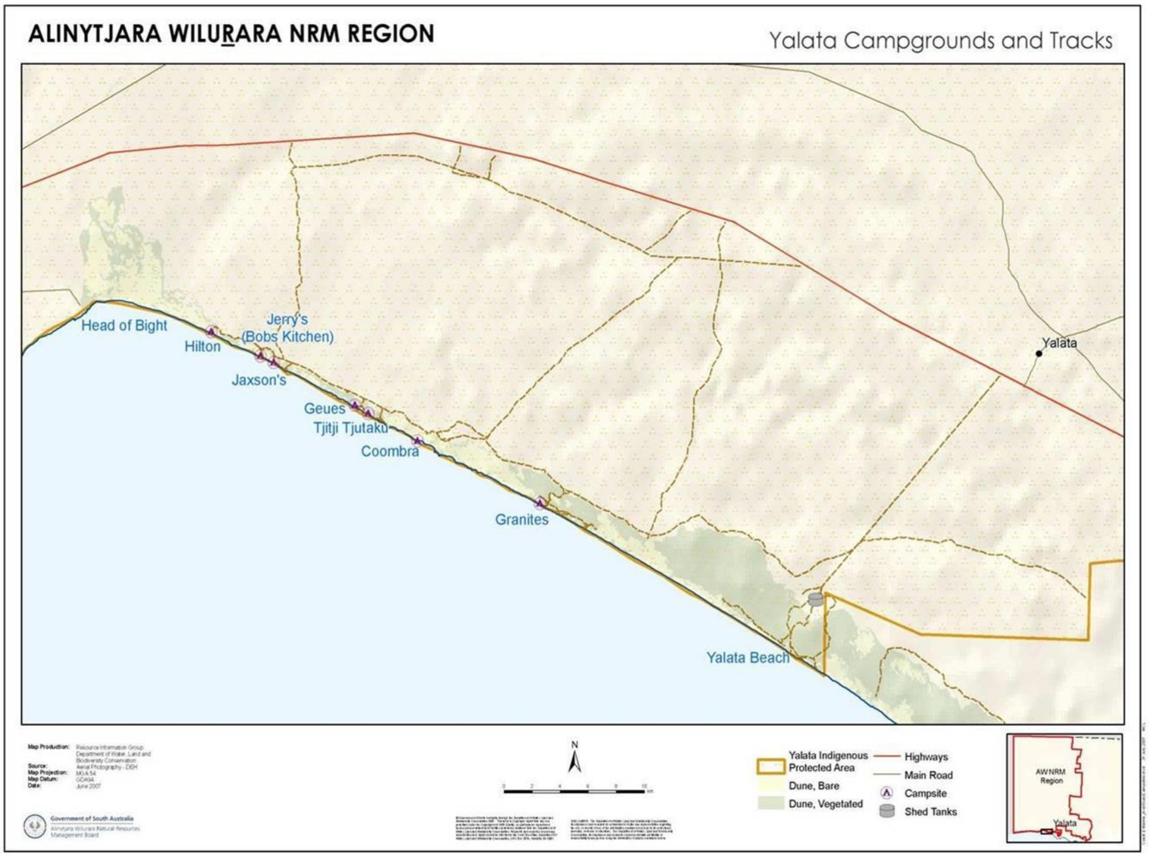


4.9 Coastal zone

The AW NRM coastline is made up of a section of the Great Australian Bight (the 70-90m high Bunda Cliffs), as well as coastal dunes, swamps and salt marsh. The coastline contains popular spots for recreational fishing and camping, as well as supporting a diverse array of marine and coastal biodiversity (AW NRM 2011). While adaptation strategies for coastal and marine biodiversity will be the focus of a separate review by the AW NRM Board, this section focuses on the implications of sea level rise for coastal activities and ecosystems. Over the period 1901 to 2010, global mean sea level rose by 0.19 [0.17 to 0.21] m (IPCC 2013). Sea levels will continue to rise with future climate change, with additional increases projected to be between 0.26 and 0.82 m by 2100 depending on the emissions scenario and climate models used (IPCC 2013).

While the impacts of mean sea level changes are significant, they may not be as destructive as the impacts of extreme sea level events such as storm surges, which are exacerbated by mean sea-level rise (CSIRO and BoM 2007). A 2005 study of Port Adelaide-Enfield seawater and stormwater flooding risk concluded that the upper-end of the IPCC AR3 (2001) sea-level rise projections (0.88m) would translate to a 1 in 100 year sea defence threshold level (incorporating sea-level rise, tidal amplification, storm surge, wave effects, further land subsidence and 300mm freeboard) of around 4.1 m, representing a much greater impact on infrastructure, communities and biodiversity than sea-level rise alone (Jacobi and Syme 2005). Even assuming a sea-level rise of 0.5 m by 2100, the AW NRM southern coastline is predicted to receive many more extreme storm surge events by 2100 (ACE CRC 2008, Department of Climate Change 2009). Such erosive events would impact upon tourist viewing and beach access infrastructure along the Yalata coastline, and present a significant risk for the camp sites located along the Yalata beach foreshore (Figure 27).

Figure 27 Camp grounds and tracks along Yalata IPA (Source: AW NRM)



Low-lying salt-marsh environments like the Yalata Swamp are also likely to be impacted by increasing sea-levels. In general, wetland and salt-marsh systems are sensitive to sea-level changes, sediment loads and the salinity of the water (Fotheringham 2010). While these systems can, in their natural state, keep pace with changing sea-level rise with continuing sedimentation and landward migration, the rate at which sea levels may rise could exceed threshold levels leading to significant negative impacts on ecosystem health and productivity. A report on the Yalata Swamp (Fotheringham 2010) found that it was at risk of changing into a shallow brine lake or wet swamp due to sea water percolating through the primary dunes as a result of sea level rise.

In addition to sea level rise, climate change is likely to impact upon the timing of key events such as the whale breeding season, due to changes in currents and temperatures. Abundance and distribution of important fish (such as mulloway) and other marine species may also change, however the impacts on individual species will need much more detailed research. Respondents in the workshops have already noticed changes in the timing of certain marine events such as whale breeding, as well as noticing changes in the types of species that were being caught.

> *Whales come in the winter. The whales are staying longer, and in the last couple of years they arrive later in the season. In the past, they would arrive around Easter time. The whales didn't rock up until July last year – it was late but then it was 100 females. Currents might be getting warmer. Fowlers Bay was 18 degrees up until a few weeks ago. The fish follow the currents and water temperatures. This year there have been few snapper, perhaps because we have cooler on-shore currents and we had a warmer sea later. There were also no salmon around. We are seeing some unusual fish, weird fish, such as tailor and Giant Travally, and turtles. An Atlantic salmon probably came up from Tasmania.*

Changes in wind direction were also noticed by respondents as a key factor in local fish abundance and dune formation/erosion, and is also something which is likely to change with future climate change:

> *When you get a decent south-easterly the sea floor is flat for a long way, there are no gutters and no mulloway. When there are northerlies the beach drops off right away and you get mulloway. The wind direction is responsible for everything you see – the fish, the waves, the dust. Some dunes are eroding onto the beach.*

The most important adaptation option is to ensure that camping and other coastal activities and assets are located away from potential increases in storm surges, particularly during king tides. A precautionary approach is warranted given the large uncertainties and range in future sea level rise estimates. As one respondent noted, the increasing demands of tourist management is a key concern, with storm surges already impacting on camp sites:

> *Our biggest job is managing tourists in summer. They need to book 12 months in advance to camp on the IPA lands. There is increasing demand and pressure from tourists. A fisherman was washed out from Yalata Beach with a storm surge and the campsite was flooded.*

Providing additional water points (e.g. shed tanks) for tourists was also highlighted as a priority in workshops with IPA rangers, to provide supplementary water in extreme heat. However, as also noted in the workshops, tanks need to be located far enough away from campsites so they don't encourage dependency, but can still be reached during emergency situations.

Monitoring of dune movement on the foreshore in partnership with the Coastal Protection Board could also help to understand the rate at which sandy beaches are eroding or accreting. Monitoring cliff retreat of the Bunda cliffs could also help to plan future access roads and any infrastructure to minimise potential damage. While the adaptation options for ecosystems like the Yalata Swamp are fairly limited, conducting repeat measurements of the underlying groundwater levels would be a way of tracking trends in sea level rise over time. Providing space for such ecosystems to retreat upslope may also allow natural colonisation by salt-marsh species in response to rising water levels.

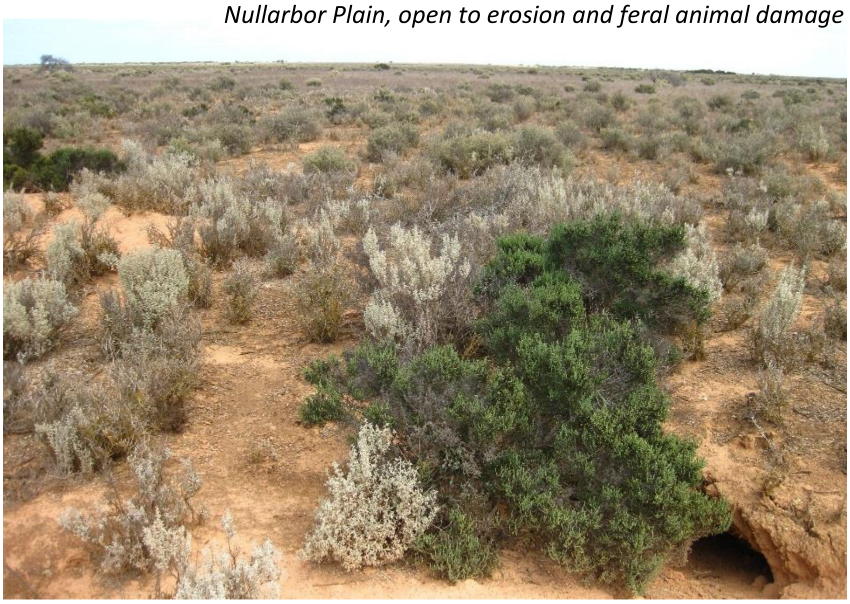
4.10 Vegetative biodiversity and carbon sequestration

Many respondents from community workshops have noticed changes in the types and densities of vegetation over the years. Changing fire regimes, introduced herbivores, and wind and water erosion have all potentially contributed to a decline in perennial vegetation in parts of the AW NRM region. Introduced species such as rabbits and camels have also prevented natural regeneration of trees:

> *You are not seeing regeneration in the Nullarbor like you used to. The old trees are there but not the young ones. Maybe it's because of longer periods without rain and the plagues of rabbits and camels which have a major impact.*

Similar reports of trees dying in the north of the AW NRM region were received during workshops, however respondents were unsure of the causes of these declines.

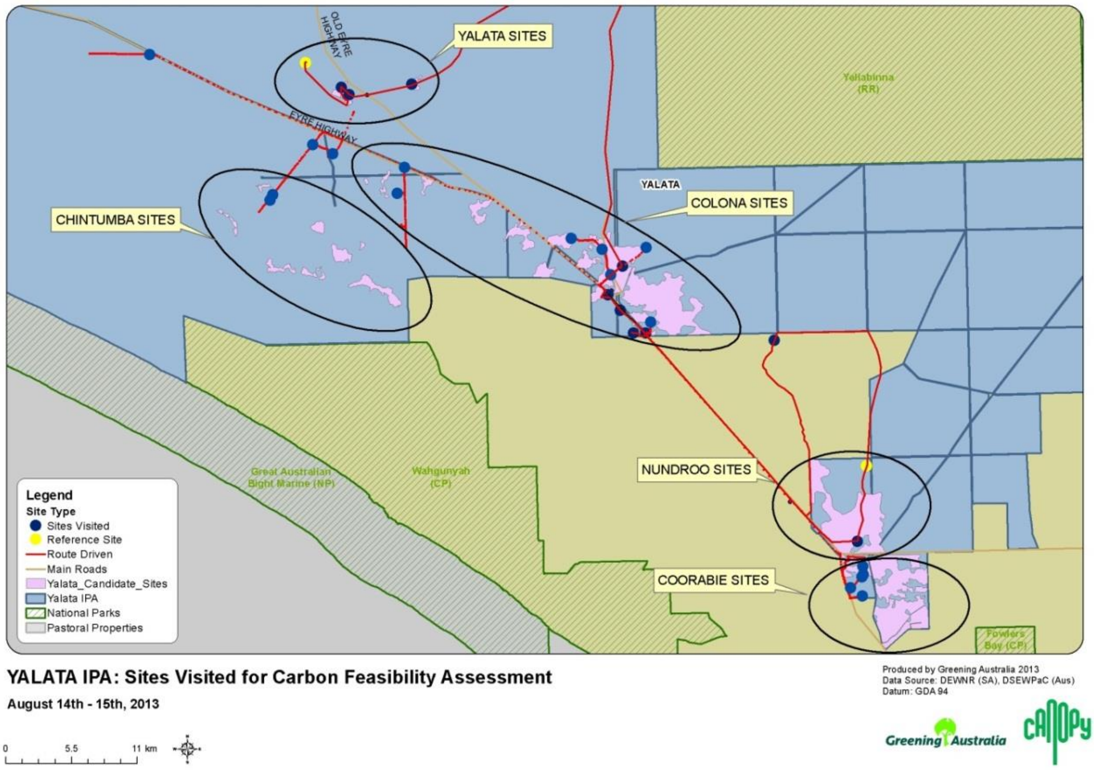
Nullarbor Plain, open to erosion and feral animal damage



The modelling work by Pavey (2014) indicates that for native species, plants, snails and lizards are likely to be most impacted by future climate change; impacts on mammals will be moderate, whereas impacts on birds and frogs will be low. As discussed in the sections on fire (Section 4.2) and invasive species (Section 4.8), climate change will lead to increased fire risk, as well as stable large feral herbivore populations, which is likely to increase the pressure on native plants within the region. Direct impacts, including more variable rainfall and hotter temperatures, will also negatively affect plant growth. These direct and indirect impacts are also likely to reduce the carbon pool stored in soils and vegetation in the rangelands (Dean and Harper 2008, Dean et al. 2012).

In the south, a scoping study has been conducted for potential Carbon Farming Initiative (CFI) tree planting activities on areas of the Yalata IPA (Figure 28) (Moore 2014). An independent financial appraisal of the project suggested the lowest breakeven cost was $26.68 per Australian Carbon Credit Unit, which is significantly above the expected price of abatement ($5-10) under the current Emissions Reduction Fund (IEC 2014). High break-even costs, combined with low carbon sequestration rates in the Yalata region, high rainfall variability, and remoteness of the site means that a much higher price on carbon is required before the project could be considered to be viable without additional financial support (IEC 2014).

Figure 28   Sites visited for carbon feasibility assessment in Yalata IPA (Source: Canopy 2013)



IEC (2014) found that other potential natural resource-based carbon offset projects, including removal of feral camels, human-induced regeneration, and forestry plantations were either ineligible or unlikely to be financially feasible in the AW NRM region. In the case of active regeneration, the approved CFI methodology requires sites to have been cleared of native vegetation, and able to form a forest cover (>20% canopy cover and >2m tall trees) in the absence of invasive species or other degrading processes. It is currently unknown whether the AW region has any areas which would meet these definitions (IEC 2014).

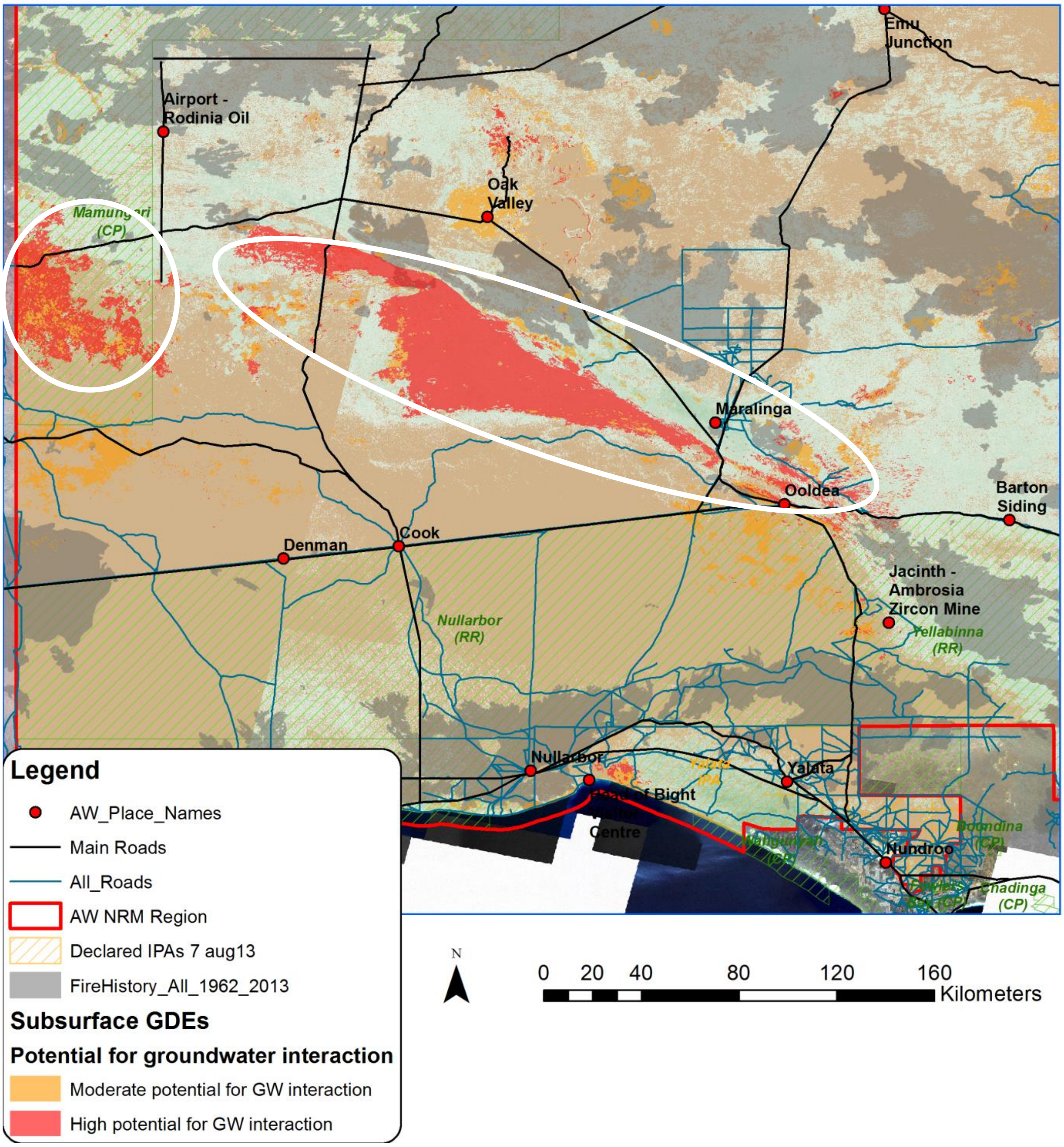
While there may be some (limited) future opportunities under the CFI in the AW NRM region, there are also substantial business risks involved, due to a combination of policy uncertainty, governance risks, financial uncertainty and risk at both international and national scales, biophysical risks due to high variability and fire ecology, social risks, and significant gaps in environmental knowledge (e.g. carbon sequestration rates, baseline information on carbon stocks, fire regimes and impacts on carbon cycle, impacts of grazing on carbon etc.). These risks were highlighted in an AW NRM workshop on CFI opportunities in the AW NRM region in late 2013. As noted above, climate change is likely to reduce the carbon sequestration potential of the rangelands due to increased fire risks, changing rainfall and higher temperatures. When combined with the already low carbon sequestration rates of managed rangeland ecosystems of 1 to 4 t-CO_2e /Ha/year (Daryanto *et al.* 2013, Witt *et al.* 2013) and the low effective price of sequestered carbon, any CFI projects in the region will need to demonstrate multiple co-benefits (e.g. for improved biodiversity, employment opportunities, invasive species control etc.) for them to be considered environmentally, economically and socially beneficial.

Focussing on managing the existing long-lived carbon assets of the AW NRM is likely to be the most pragmatic approach to mitigating emissions, with or without a price placed on the carbon. This conclusion recognises that most landscapes within the region with perhaps the exception of the Great Victoria Desert have evolved over time to respond to frequent wildfire regimes and subsequent losses of fixed carbon, particularly in grasses and soils. Managing threatening processes to carbon assets, such as inappropriate fire regimes and feral grazing pressure, represents an ecosystem-management perspective, compared with attempts to directly plant trees which may or may not survive. Managing the context (often called parametric management, or supply-side management), or the controlling processes of the system of interest, has been shown to be more effective in highly variable and unpredictable environments compared with trying to manage system outputs (i.e. trees) directly (Holling et al. 1995, Acheson et al. 1998, Allen et al. 2002, Tongway and Ludwig 2011).

Refuge areas for native biodiversity at a broad regional scale within the AW NRM region include the APY Ranges and the Nullarbor Plain (Pavey 2014). At a sub-regional scale, there are several features of the AW NRM region that stand out as potential targets for enhanced biodiversity and long-lived carbon management. These features include the northern edge of the Nullarbor Plain and southern third of the Mamungari Conservation Park which show persistent green remotely-sensed vegetation indicating carbon fixation. These areas correlate reasonably well with ground-water dependant vegetation, and they also have no fire history recorded, suggesting they are relatively long-lived carbon assets (Figure 29). This vegetation is in general a mixture of *Acacia ligulata* shrubland, with patches of *Eucalyptus concinna* and *Casuarina pauper / acacia papyrocarpa* low woodland.

Quandong

Figure 29 Southern AW NRM region, indicating potential management priority areas for carbon (white circles). Areas to the north of the Nullarbor Plain and also within the Mamungari Conservation Park show moderate to high potential for groundwater interaction (orange and red respectively), correlation with remotely-sensed persistent green vegetation (stronger green = more persistent), and little to no recorded fire history (1962-2013, fire scars shown in grey).

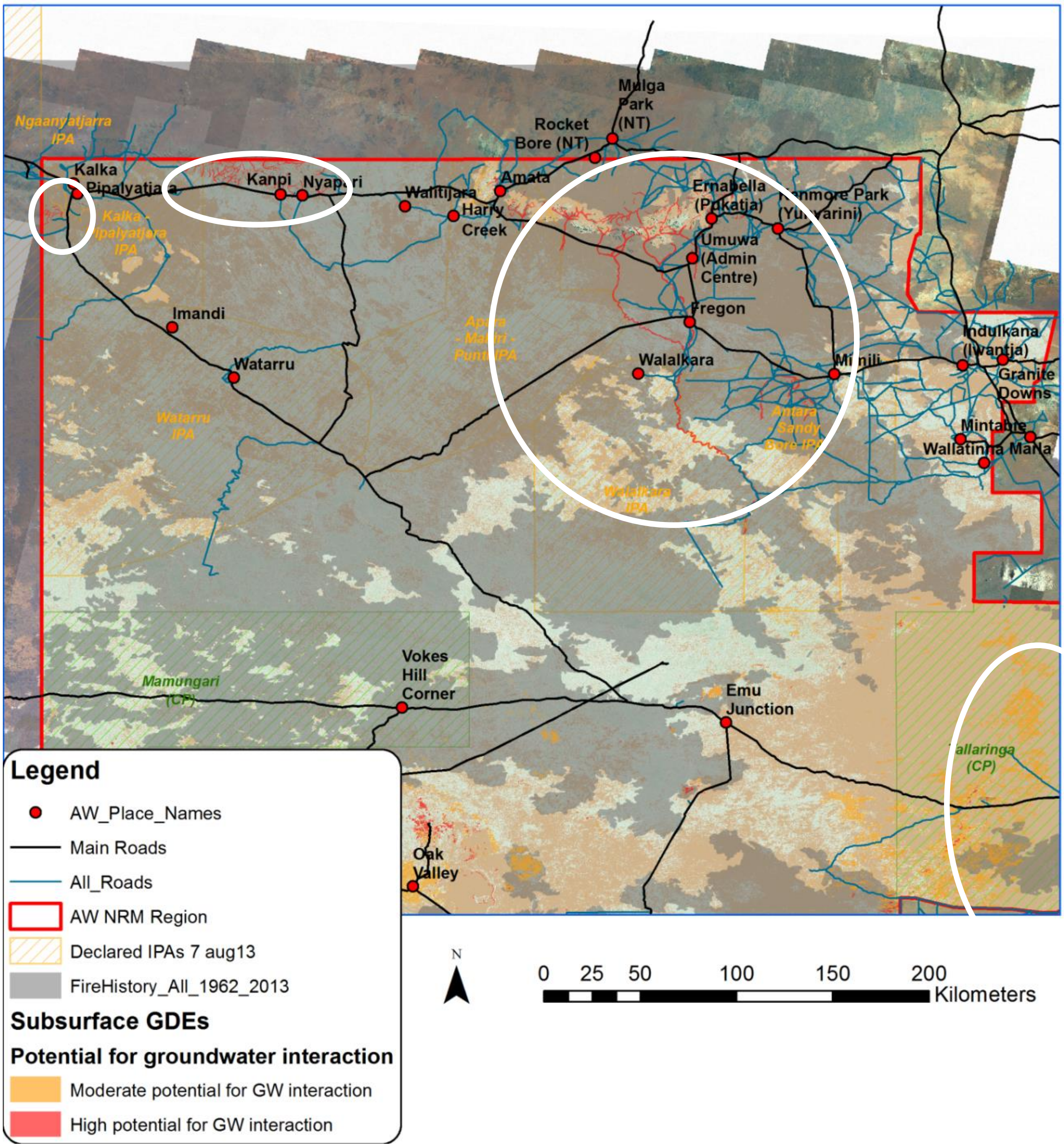


These areas should be verified in terms of their long-term stability by more detailed aerial imagery analysis, which is currently being conducted by AW NRM as part of Stream 1 of the NRM Planning for Climate Change Fund, as well as ground-truthing to determine vegetation types. Management activities for these regions could include controlling the southward spread of Buffel grass and controlling feral herbivores which limit natural regeneration.

In the north, the major ephemeral drainage lines of the Mann and Musgrave Ranges, especially Officer Creek and tributaries running through Fregon, and to a lesser extent the creeks around Kanpi-Nyapari and Kalka-Pipalyatjara, are the only areas identified as having high potential for groundwater interaction (Figure 30). These areas represent the *Eucalyptus camaldulensis* river beds along the major drainage channels. Drainage corridors in rangeland environments have been argued to offer the greatest potential for long-term carbon sequestration, due to their high levels of long-lived woody biomass compared with surrounding grass-dominated landscapes (Dean *et al.* 2012). There is also an area of mulga woodland vegetation with moderate potential for groundwater interaction within the Tallaringa Conservation Park in the Eastern APY Lands which could be investigated for carbon sequestration opportunities, given it has also been spared from wildfire in the last 50 years.

Eucalyptus camaldulensis *growing along river beds in the APY Lands*

Figure 30 Northern AW NRM region, indicating potential management priority areas for carbon (white circles). The major drainage lines of the APY ranges represent key long-lived biomass reserves in the semi-arid landscape



It is interesting to note from Figure 30 that the vast majority of the APY Lands have at some time in the past 50 years been burnt (shown in grey), which indicates what a fire-prone landscape it is, and how risky permanent plantings or regeneration under the CFI is likely to be. However while the majority of the landscape has been burned within the last 50 years, there are also unburned areas association with the highest peaks of the Musgrave Ranges, in the headwaters of the Officer Basin – representing country that is likely to be either too sparse in vegetation or too rocky to carry larger fires. Similarly the majority of the groundwater-dependant vegetation in Tallaringa Conservation Park has not been burnt within the recorded observation period. Recent aerial imagery analysis as part of Stream 1 NRM Planning for Climate Change Fund has identified relative rates of woody vegetation loss across the northern APY Lands (Figure 31).

Figure 31 Analysis of aerial photographs from 1963 to 2007 show relative rates of loss of woody vegetation across the northern APY Lands.

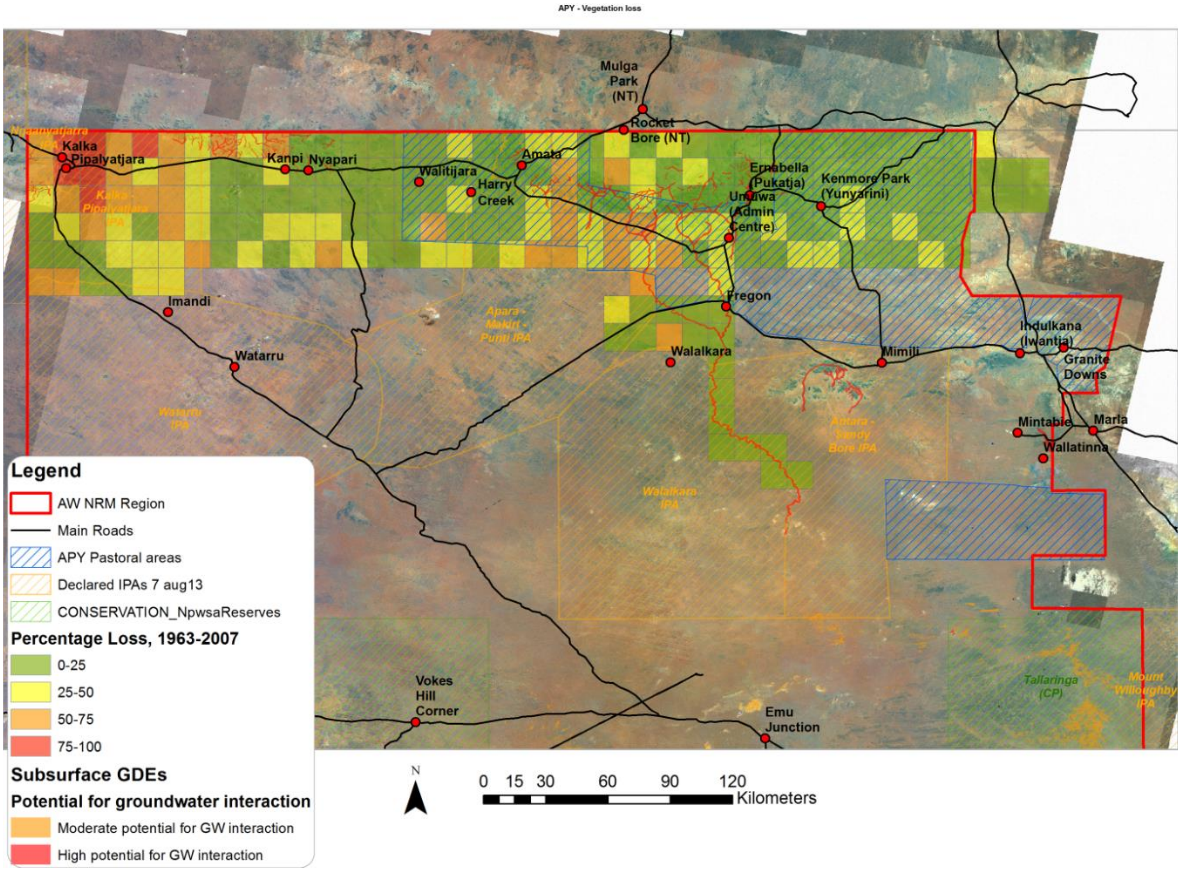


Figure 31 suggests that the headwaters of the Officer Basin near Ernabella, the lower reaches of the Officer Creek bordering Walalkara and Antara-Sandy Bore, and the short drainage lines around Kanpi-Nyapari are the least changed riparian corridors since aerial photographs were taken in the 1960's, and should be accorded high conservation priority. In contrast, the areas around Kalka-Pipalyatjara appear to have experienced significant loss, suggesting less of a priority to manage the remaining long-lived carbon assets – or the potential for significant regeneration. Further work on aerial imagery analysis would allow for targeted prioritisation of potential long-lived carbon assets in Tallaringa Conservation Park and around Mimili/Everard Ranges. More detailed analysis at a higher resolution within these drainage lines and groundwater dependant vegetation communities could also further help to distinguish hot spots of conservation value.

Management activities in high-conservation zones should include ensuring livestock and large feral herbivores do not concentrate and cause bank erosion, through careful waterpoint location and fencing; and controlling Buffel grass in and adjacent to these corridors (Dean *et al.* 2012). However care needs to be taken in managing livestock and large feral herbivores in these areas, as a reduction in grazing pressure may counter-productively increase Buffel grass growth, leading to increases in fire intensity and frequency, and overall declines in carbon sequestration potential (Dean and Harper 2008, Dean et al. 2012). On the other hand, if Buffel is not controlled, these drainage channels could act as wicks in spreading fire along and outwards from the riparian corridors. Starting control of Buffel grass as far as possible upstream and working methodically downstream reduces its potential to recolonise from seeds distributed during flooding events. Road crossings of creeks are another key focus area, as Buffel seed can easily get established along these crossings from passing cars and livestock.

4.11 Summary of themes

The following tables summarise the preceding themes and corresponding adaptation responses (both short and longer-term), distinguishing between the north and south of the AW NRM region (Tables 12 and 13; Figures 32 and 33). Where relevant, adaptation responses are followed by bracketed notes, e.g. '(W1)' to indicate that they are supported by existing actions in current NRM Plan, using the numbering convention outlined in Section 2.2 of this report. Where no bracketed note exists, it indicates a new action not currently supported in the existing NRM Plan. While adaptation responses have been grouped into themes, it is important to recognise the need for integrative, holistic approaches to adaptation rather than piecemeal efforts. Projects that combine several adaptation benefits, for example, integrated management of bushfoods, or long-lived carbon assets, or those with far-reaching consequences, such as managing Buffel grass or increasing resilience to extreme events, should be given priority over more isolated and/or limited activities.

Priority adaptation projects in the region include:

In the north:

- **Protection of long-lived carbon assets** in major drainage channels in APY (primarily headwaters and lowers reaches of Officer Creek catchment, but also around Kanpi-Nyapari)
- **Designation of bushfood zones** in areas of high hunting, invasive species, fire or community pressures to reduce non-climatic pressures on native species within vital ecosystems
- **Integrated management of fire and Buffel grass along roads** as these represent the key areas of ignition and also the major sources of Buffel grass seed spread
- **Adaptation to heatwaves,** for communities, stock and native species, particularly to ensure vulnerable community members are cared for
- **Managing flooding** by reducing risks to key infrastructure, and providing community reserves of fuel, food, and medicine
- **Developing seasonal calendars** as monitoring tools to track changes in flowering, breeding and other phenomena over time

In the south:

- **Protection of long-lived carbon assets** in the southern third of Mamungari Conservation Park and north of the Nullarbor Plain
- **Managing southward migration of Buffel grass** by concentrating control along major road and rail lines and in Yalata community
- **Reducing the risks of sea level rise** by relocating camp sites higher and further away from the shoreline
- **Adaptation to heatwaves** for communities and native species, particularly to ensure vulnerable community members are cared for
- **Developing seasonal calendars** as monitoring tools to track changes in flowering, breeding and other phenomena over time

Table 12 Summary of themes and adaptation responses in the North

	Buffel grass	Fire management	Heatwaves	Bushfoods	Water management	Grazing	Feral animals	Biodiversity and Carbon
Current State	Buffel grass is widespread, and negatively impacting on important bushfoods and biodiversity	Fire regimes have changed dramatically since European colonisation, due to less traditional burning and introduction of Buffel grass Fire presents a significant risk to communities and infrastructure in the APY Lands given the current lack of response capacity	Heatwaves are impacting on communities, particularly the elderly or sick who cannot easily leave the lands during the hotter months Blackouts are common under peak loads from air conditioning Recent heatwaves have negatively impacted on biodiversity	Bushfoods are declining due to a combination of Buffel grass invasion, over-hunting, feral animal competition and predation, and cattle grazing	Groundwater levels are already declining in some communities and pastoral stations due to over-extraction Rockholes are being over-exploited and damaged by feral camels Flooding has impacted on communities, damaging infrastructure and cutting off roads and access to food. People staying in homelands get cut off for weeks	Grazing is destroying bushfoods in some areas, as well as biodiversity Stock waters are drying up due to over-extraction	Feral animals, including camels, donkeys, horses, red foxes, rabbits and cats are causing significant environmental damage, including damage to bushfoods and sacred sites such as rockholes	Long-term decline in woody biomass (e.g. mulga woodlands) has been observed in parts of the AW NRM region due to changing fire regimes and introduction of feral herbivores Carbon planting is marginal in most of the region due to low rainfall, and frequent fire regimes which prevent long-term carbon accumulation
Future Issues with Climate Change	Buffel is unlikely to be controlled over large areas due to the high likelihood of reinvasion and suitability to a warmer, higher CO_2 climate	Fire risk is likely to increase in a changing climate, due to a combination of hotter temperatures which extend the fire season and increase the number of extreme fire weather days, larger summer rains which will increase the amount of biomass and hence fuel loads, and the predicted spread of Buffel grass. The window for prescribed burning is likely to shorten	Heatwaves are likely to get hotter, longer and more frequent	The existing drivers of bushfood decline are likely to intensify with future climate change, as well as increases in heatwaves and more variable rainfall Climate change will change the timing of important seasonal events such as hibernation and flowering/fruiting	Larger downpours may increase aquifer recharge in the central ranges, but increasing temperatures will put increase pressure on groundwater extraction to supply communities and stock, and for emergency fire management Heavier rains will likely increase flood impacts	Increasing temperatures and heatwaves and more variable rainfall will put increased pressure on stock and supporting resources (water, grazing land)	Large feral herbivores (camels, donkeys, and horses) as well as the red fox present the biggest threats as a result of climate change, with these species projected to either remain stable (feral herbivores) or increase in abundance (red fox). In contrast, rabbits, cats and goats are projected to decrease either in abundance or distribution	The drivers of woodland decline are likely to intensify with climate change CFI activities present significant risks due to increased fire intensity and decreases in natural carbon sequestration rates due to hotter temperatures and increased fire frequencies

	Buffel grass	Fire management	Heatwaves	Bushfoods	Water management	Grazing	Feral animals	Biodiversity and Carbon
Short-term adaptation priorities (bracketed notes, e.g. 'W1' indicate support of existing actions in current NRM Plan)	Roadside control of Buffel grass (C4) Prioritise control within major drainage lines and creeklines, working from upstream down (see Carbon and Biodiversity) Asset protection (built and natural assets) by prescribed burning, herbicide application, grading, or controlled grazing Monitor Buffel grass in the southern parts of Walalkara, Antara-Sandy Bore and Watarru IPAs	Concentrate fire management along major roads, as these are the highest sources of ignition. (C10) Increase prescribed burning around woodland vegetation (e.g. Desert Oaks between Amata and Kanpi, mulga woodlands in Watarru IPA, and along major drainage lines) (C10)	Ensure access to air-conditioning and swimming pools during summer months Manage peak loads with spare generators or solar PV to prevent blackouts Ensure stock and mustered animals have access to adequate shade and water Provide alternative water points for native animals	Conduct patch burning to reinstate traditional fire seral mosaics, and monitor post-fire recovery of plants and animals (C10, C12) Manage feral animals to reduce competition and predation (C3)	Implement groundwater resource monitoring and develop alternative supplies for high risk communities, which include Amata, Ernabella, Kenmore Park and Fregon. (W11, W15) Ensure rockholes are cleaned regularly to store maximum water Ensure timely maintenance of stock waters to prevent stock dehydration and stress Conduct audit of significant rockholes and other aquatic refuges using Davis' (2014) methodology, combined with cultural significance weighting, to determine a management priority list of surface water resources and groundwater dependant ecosystems, such as the major creeklines (C9, W3, W7, W21)	Conduct regular community-based monitoring of existing grazing photopoints (C2) Set and enforce stocking rates based on existing pasture coverage and quality Ensure shaded areas are available for stock to rest during heat waves to reduce stress Shade stock waters to reduce evaporation rates Limit stock access to creeklines to reduce damage to long-lived carbon assets	Construct mustering yards for feral herbivores in line with Feral Animal Management infrastructure plan (AW NRM 2014) (C3) Ensure adequate shade and water is available to prevent heat-related stress on mustered stock Minimise stock holding times before they are removed to reduce heat-related stress	Prioritise management of major drainage lines (e.g. Officer Creek) – and control livestock/feral herbivore pressure and Buffel grass within and adjacent to these areas

	Buffel grass	Fire management	Heatwaves	Bushfoods	Water management	Grazing	Feral animals	Biodiversity and Carbon
Longer-term resilience actions	Develop biocontrol measures Develop a use for harvested Buffel grass – e.g. as fuel, fodder, biochar feedstock, etc.	Develop community CFS programs which involve interested community members in fire management and training for both traditional cultural reasons and also asset protection activities. This could be developed through the TAFE as an accredited training program (P11) Develop fire fund which is tied to seasonal rainfall to provide adequate funding for prescribed burning following wet years when the need is greater. Deposits can be made every year, with withdrawals made only after exceptionally wet periods Consolidate fire management activities as the fire season extends – perhaps using casual staff or other flexible arrangements to focus activity in the brief window of opportunity before the fire season begins	Improve building thermal performance, increase shade trees, improve community health Consider temporary migration for at-risk people within communities during the summer months Schedule the majority of NRM work during the cooler months of the year Consider assisted migration of sensitive species (e.g. Warru) to higher, cooler refuge areas	Designate refuge areas where bushfoods are more intensively managed through conservation works and controls on hunting, to provide surrounding areas with greater hunting opportunities These conservation zones could also be managed for carbon assets where appropriate to achieve multiple benefits to communities Implement community-based monitoring of catch effort and yield to keep an eye on bushfoods that are under threat from over-harvesting Implement community-based monitoring of seasonal events to track changes in bushfoods over time (C26, C27, P7, P10, P13, P19)	Implement groundwater resource monitoring for all major communities in the region (W15) Implement water conservation measures in communities, including transparent information on household water use, and investigate pricing mechanisms to regulate overuse. (W16) Utilise rainwater harvesting techniques to passively irrigate community trees and reduce peak stormwater flows and flood risk Development supplemental supply, with larger rainwater tanks sized for projected increases in peak rainfall intensity Investigate ways of augmenting inflows into rockholes through swales, and reducing outflows by fencing feral animals out and shading rockholes with vegetation or shade cloth Ensure essential community infrastructure is located away from flood-prone areas	Monitor long-term seasonal forecasts Stock for the worst years, not the best to conserve perennial vegetation Create ponding banks where there is erosion potential to capture larger rainfall events, reduce erosion and grow productive perennial grasses Use smaller paddocks, more water points and higher rotations with long rest periods Breed cattle as part of operations and select for resilient stock	Encourage dingo populations in order to increase predation of and competition with the red fox, which is the only species projected to increase in abundance with future climate change. Aerial culling of camels may support larger dingo populations by allowing them to feed on the carcasses Develop local abattoir processing capability and infrastructure for mustered feral herbivores to reduce heat stress on animals, provide local employment, and provide a buffer against heatwaves (e.g. cold storage) or floods preventing truck access and decline in animal condition	Manage threatening process (particularly inappropriate fire regimes and feral herbivores – C3, C10) to promote natural carbon regeneration, rather than planting trees Ensure riparian vegetation (predominantly *Eucalyptus camaldulensis*) is regenerating naturally through ongoing monitoring

Figure 32 Subregional-scale summary of adaptation responses in the North (finer-scaled adaptation responses omitted from this figure)

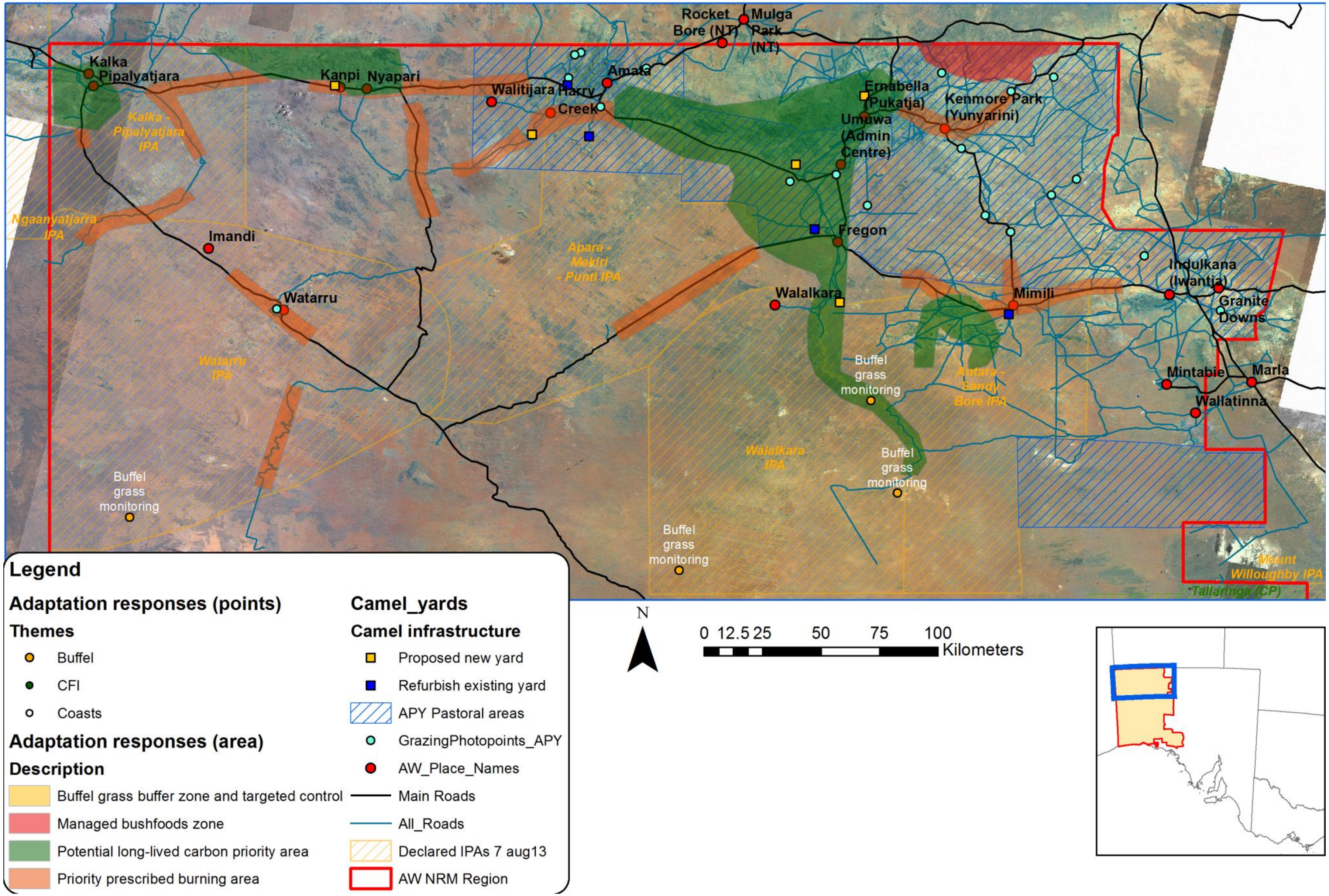


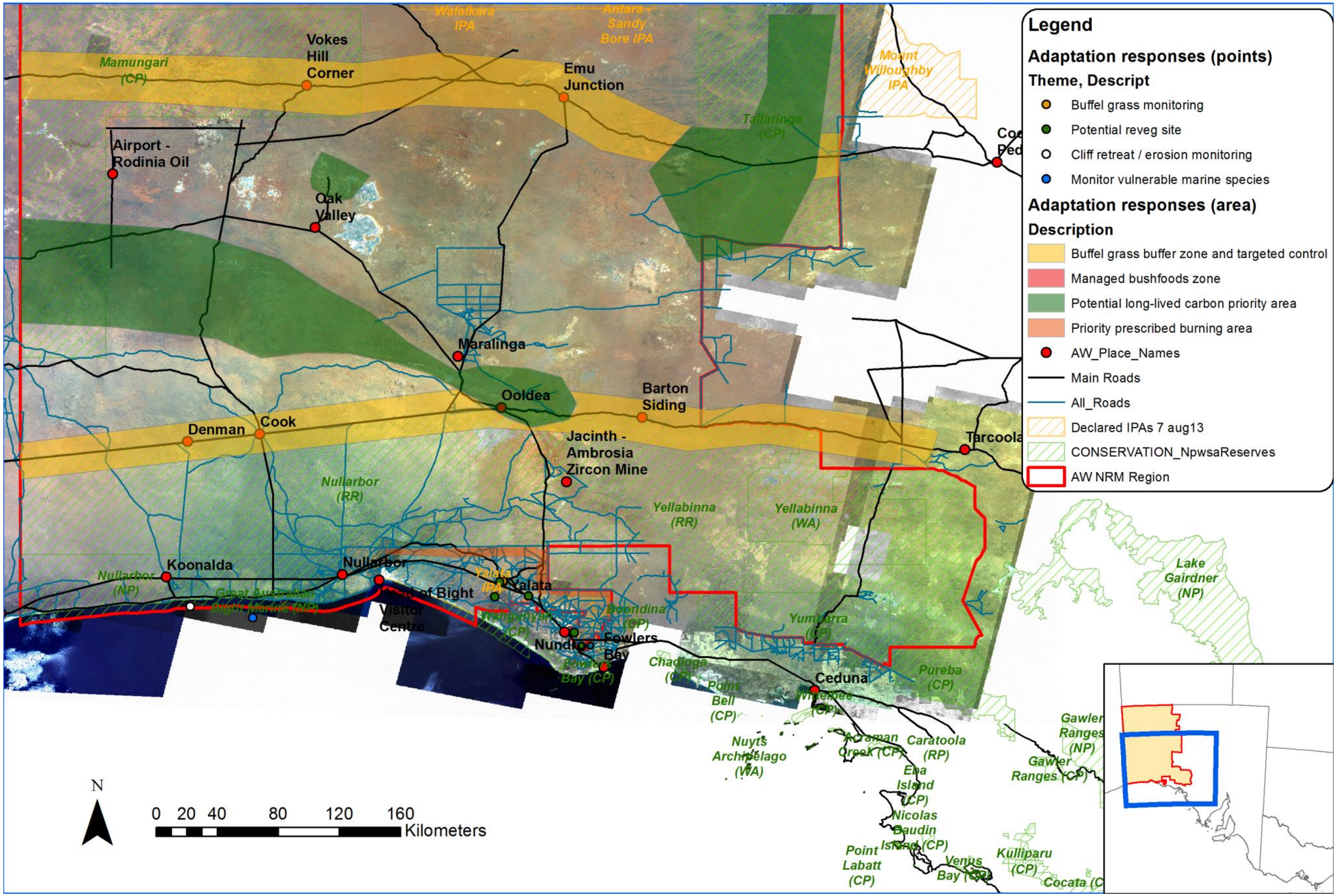
Table 13 Summary of themes and adaptation responses in the South

	Buffel grass	Fire management	Heatwaves	Bushfoods	Water management	Feral animals	Coastal zone	Biodiversity and Carbon
Current State	Buffel grass has been observed in Yalata Community, as well as along roads and the rail line	Fire regimes have changed since European colonisation. Fire presents a significant risk to IPA management given the lack of response capacity	Heatwaves are impacting on communities, with blackouts common under peak loads in summer from air conditioning Recent heatwaves have negatively impacted on biodiversity	Some bushfoods such as red kangaroo are declining due to a combination of over-hunting and feral animal competition (particularly rabbits and camels). Dingo populations have controlled foxes and cats to some extent Changes were noticed in some fish species, linked to changes in currents and ocean temperature	Groundwater levels in Yalata are declining due to over-use Groundwater in Oak Valley is depleted – water is sometimes brought up from Yalata Insufficient emergency water for tourists and fire-fighting	Camels are less of an issue for Yalata IPA compared with further north Rabbits, cats and foxes all impact on native biodiversity	Storm surges have washed out low-lying campsites in the past Changing ocean currents and temperatures have led to unusual fish and other marine species being identified along the AW coastline	Long-term decline in woody biomass has been observed in parts of the AW NRM region due to changing fire regimes and introduction of feral herbivores Carbon plantings may be viable in the southern edge of Yalata IPA
Future Issues with Climate Change	Buffel grass is likely to spread further south in a warming climate. Containment is essential to prevent further spread which will be impossible to remove if it becomes established	Fire risk is likely to increase in a changing climate, due to a combination of hotter temperatures which extend the fire season and increase the number of extreme fire weather days, and the predicted spread of Buffel grass. The window for prescribed burning is likely to shorten	Heatwaves are likely to get hotter, longer and more frequent	The existing drivers of bushfood decline are likely to intensify with future climate change, as well as increases in heatwaves and more variable rainfall Climate change will change the timing of important seasonal events such as hibernation and flowering/fruiting, and may further change fish patterns due to change in currents and temperature	Oak Valley and Yalata are at low risk of climate change impacting on groundwater levels, but both communities are at risk from over-extraction Hotter temperatures and increased fire risk will increase the need for emergency water supplies, as well as increase the demand for water within communities	Large feral herbivores (camels, donkeys, and horses) as well as the red fox present the biggest threats as a result of climate change, with these species projected to either remain stable (feral herbivores) or increase in abundance (red fox). In contrast, rabbits, cats and goats are projected to decrease either in abundance or distribution	Rising sea levels and associated storm surges will further threaten coastal camps Changing coastal patterns (e.g. wave direction, sea temperature, wind erosion) may change habitat suitability for species	The drivers of woodland decline are likely to intensify with climate change CFI activities present significant risks due to increased fire intensity and decreases in natural carbon sequestration

	Buffel grass	**Fire management**	**Heatwaves**	**Bushfoods**	**Water management**	**Feral animals**	**Coastal zone**	**Biodiversity and Carbon**
Adaptation priorities (bracketed notes, e.g. 'W1' indicate support of existing actions in current NRM Plan)	Containment and eradication of Buffel around Yalata is a high priority Quarantine measures which prevent cars from spreading seed from further north should be investigated (C2) Control along the rail line and major roads to prevent Buffel spreading further south is also a priority (C2)	Increase prescribed burning on northern Yalata IPA boundary to reduce grass fires spreading from further north (C10) Increase the number of shed tanks in the more remote sections of Yalata IPA to improve fire-fighting capacity	Ensure access to air-conditioning and swimming pools during summer months Manage peak loads with spare generators or solar PV	Conduct patch burning to reinstate traditional fire seral mosaics, and monitor post-fire recovery of plants and animals (C10, C12) Manage feral animals to reduce competition and predation (C3)	Establish shed tanks in strategic locations for emergency water supplies for tourists and fire-fighting Implement water conservation measures in communities, including transparent information on household water use, and investigate pricing mechanisms to regulate overuse. (W13, W16)	Continue aerial culling programs for feral camels (C3) Continue baiting programs for foxes, and control for rabbits (C3)	Relocate low-lying campsites further away from the shoreline, and provide supplementary water points for emergency use Record species caught by recreational fishers, perhaps by promoting the Redmap software: http://www.redmap.org.au/ (C27, C28) Establish monitoring points to record dune movement over time Track trends in groundwater levels at Yalata Swamp	Investigate carbon potential of groundwater-dependant vegetation to the north of the Nullarbor Plain, and in the southern third of Mamungari Conservation Park

	Buffel grass	Fire management	Heatwaves	Bushfoods	Water management	Feral animals	Coastal zone	Biodiversity and Carbon
Longer-term resilience actions	Develop bio-control measures – this may be particularly applicable in the South where Buffel is not such an important pasture species compared with northern Australia	Greater funding for training and coordinated responses to fire through local CFS teams Concentrate fire management activities and funding to the coolest part of the year to achieve prescribed burning objectives before the fire season	Improve building thermal performance, increase shade trees, improve community health Consider temporary migration for at-risk people within communities during the summer months Schedule the majority of NRM work during the cooler months of the year	Designate refuge areas where bushfoods are more intensively managed through conservation works and controls on hunting, to provide surrounding areas with greater hunting opportunities These conservation zones could also be managed for carbon assets where appropriate to achieve multiple benefits to communities (e.g. to the north of the Nullarbor Plain) Implement community-based monitoring of catch effort and yield to keep an eye on bushfoods that are under threat from over-harvesting Implement community-based monitoring of seasonal events to track changes in bushfoods, whales and fish over time (C26, C27, P7, P10, P13, P19) Encourage dingo populations to increase predation on foxes and cats	Development supplemental supply, with larger rainwater tanks sized for projected increases in peak rainfall intensity and longer dry periods	Encourage dingo populations in order to increase predation of and competition with the red fox, which is the only species projected to increase in abundance with future climate change. Aerial culling of camels may support larger dingo populations by allowing them to feed on the carcasses	Provide space for swamp ecosystems to retreat in-land and allow for natural colonisation by salt-marsh species in response to rising water levels Determine and monitor cliff retreat rates and plan access roads and other infrastructure to minimise impacts of cliff retreat	Manage existing long-lived carbon assets by controlling threatening process (particularly inappropriate fire regimes and feral herbivores) to promote natural carbon regeneration, rather than planting trees which carries greater risks

Figure 33 Subregional-scale summary of adaptation responses in the South (finer-scaled adaptation responses omitted from this figure)



5. Knowledge gaps and priorities for future work

5.1 Knowledge gaps

The AW NRM region is characterised by a lack of scientific data on the one hand, but on the other hand, contains a rich source of traditional and local knowledge. This report has attempted to focus on local community concerns and current issues as the basis for informing future adaptation priorities. However, there are a number of knowledge gaps that will need further research to help guide management decisions and adaptation priorities. These gaps have been identified in the course of this project, as well as from discussions with AW staff and rangers. Many of the adaptation responses suggested in this report will address these knowledge gaps over time, but some gaps may need additional research and support to guide appropriate adaptation.

Key knowledge gaps include:

- Determining groundwater trends and extraction rates for communities (particularly Amata, Fregon, Pipalyatjara, Ernabella and Kenmore Park), mining leases and pastoral properties to determine whether extraction rates are sustainable, and, if not, to prioritise alternative supplies
- Categorising and prioritising management of surface waters and groundwater-dependent ecosystems according to ecological and cultural values
- Determining how threatened species will respond to increased fire frequency and intensity
- Determining carbon sequestration rates and stocks for different vegetation communities across the region (e.g. mulga woodlands, marble gum, creeklines, desert oak communities), as well as potential sequestration rates for de-stocking or managing total grazing pressure on rangelands
- Understanding the levels of hunting pressure on local bushfoods, and how communities are responding to lack of bushfood availability (e.g. by driving long distances). Recording catch effort and return could help in assessing local bushfood demand while respecting the need for privacy of preferred hunting grounds, and help in designing adequate reserves to support population increases of particular species (e.g. red kangaroos)

5.2 Priorities for future work

1. Utilise future SA State Government Climate Change Adaptation Framework funding (DEWNR 2014) to embed and integrate this report's recommendations into other related sectors (e.g. health, emergency management, education, mining).

   This report represents the culmination of four years of work between the University of Adelaide, the Alinytjara Wilu_ara NRM Board and the region's communities. The authors have produced an integrated assessment of climate change risks to natural resources (Bardsley and Wiseman 2012a), looked at community-based monitoring opportunities in the region (Wiseman and Bardsley 2013a), and finally, extended this work into detailed spatial adaptation plans and priorities for the region. Rather than re-inventing the wheel as part of the State Adaptation Framework (which requires regions to conduct an integrated vulnerability assessment, engage communities, and develop adaptation action plans – DEWNR 2012), funding through the Framework could be used to promote this report's findings and develop cross-sectoral agreement on the ways forward for NRM in the AW region. Given the high levels of community engagement fatigue observed in communities, perhaps communities that have already been consulted on environmental change issues should not be asked to run through the same issues again and rather consultation could focus on communities that were not consulted such as Maralinga Tjarutja and Oak Valley (see Point 3) and on developing opportunities for integration and shared activity with other SA Government sectors.

2. Use Healthy Country Planning as the framework to operationalise the recommendations in this report. Healthy Country Plans (also called Conservation Action Plans) aim to translate cultural and ecological objectives and goals into detailed work plans (The Nature Conservancy 2014). The level of detail proposed for these Plans is just what is required in order to take the sub-regional scale recommendations in this report (e.g. develop a bushfood management zone to the NW of Ernabella) and turn them into detailed actionable guides on how to make this happen (i.e. who will do the work, where will the funding come from, in what timeframe, with what benefits, and using what indicators for success).

   The spatial maps developed in the course of this work could be used for future Healthy Country Planning to take back to communities and refine the information, rather than re-starting conversations about Buffel, camels, fire etc. from scratch. The spatial data layering approach, using the themes discussed in this report, could be also be utilised more broadly for community consultation in the region, so that workshops are able to provide relevant information to other projects and workshops, as well as utilising past information, without needing to go through the same steps each time community views are needed. The spatial data could also be integrated with project mapping in the AW NRM region, which is currently underway in response to earlier recommendations provided to the Board, to identify areas that are relatively well understood and others that are less known across the region.

3. Communicate workshop results to communities, and consult any remaining communities that were not covered in this project (particularly Maralinga Tjarutja and Oak Valley in the central sub-region) utilising a similar framework for engagement and to integrate into Healthy Country Planning.

   A short film discussing the project's findings could be a good way of presenting results back to communities and providing a forum for group discussion about next steps, changes to any information, etc. The community handbooks developed as part of this project will be another tool for communicating results and gathering feedback from communities.

6. Conclusions

The AW NRM region has already been experiencing climatic change, with the region becoming hotter over the past century, and wetter over the past few decades. Future climate change is likely to make the AW NRM region even hotter, with longer hotter heatwaves, as well as increasing rainfall variability. In the north, there may be an increase in extreme rainfall intensity at times, particularly over the summer due to an increased summer monsoon in the north of Australia. In the south, a stronger drying trend is likely over all seasons.

While these changes will have flow-on impacts on people and country, there are many things that communities in the region can do to help prepare for future change. Protecting long-lived carbon assets, managing fire, controlling Buffel grass and other invasive species, protecting bushfoods, managing flooding, and recording and monitoring seasonal changes are some of the activities that will help people and country adapt to a changing climate. Many of these activities are already happening, but could be strengthened and supported for their value in adapting to climate change. Importantly, most activities to prepare for climate change are also good ways of caring for country anyway – they represent 'win-win' actions that will make a difference now and in the future.

There is one other broader conclusion that emerges from this work within remote indigenous communities over the last four years, which is relevant to a strategic response to environmental change across the AW NRM region. People want to live on country, understand country and make country healthy again. At the moment, insufficient support is provided to remote indigenous communities to make full use of the incredible local human resources for sustainable environmental management in the remote north-west of SA. That could be rectified without significant additional costs to Australia, but would provide enormous benefits in regards to managing changing environmental conditions; providing opportunities for training and employment; as well as renewing and strengthening the traditional socio-ecological relationships which remain a vital component of the heritage of South Australia.

Traditional Owners visiting cultural sites in Mamungari Conservation Park

7. Appendices

Appendix 1 Summary of Stream 2 work and implications for the AW NRM region

Davis J (2014) *Australian rangelands and climate change – aquatic refugia*. Ninti One Limited and CSIRO, Alice Springs

- Provides general prioritisation list for aquatic refugia based on ecological value (not cultural value)
- Provides decision tree to support adaptation planning for individual aquatic refuges
- No permanent water bodies provided by AW, but could be developed and analysed by AW using the tools outlined above
- Indirect impacts (water use, feral animals etc.) are likely to be larger than direct climate change impacts – these need to be managed

Scott JK (2014) *Australian rangelands and climate change –* Cenchrus ciliaris *(buffel grass)*. Ninti One Limited and CSIRO, Alice Springs

- Buffel will remain competitive in a warmer climate, and responds quicker after fire in an elevated CO_2 climate
- Modelling indicates Buffel will move further south with future climate change
- Containment strategies are needed for high-value assets, as eradication is unlikely to be achieved, and reinvasion is highly likely

Bastin G (2014) *Australian rangelands and climate change – dust*. Ninti One Limited and CSIRO, Alice Springs

- Dust storms are likely to continue with climate change, and may increase due to longer drought periods, hotter and more frequent heatwaves, and decreased humidity
- Maintaining a minimum ground cover on the major erodible soil types is critical to reduce wind erosion and subsequent dust storms. Reducing total grazing pressure during dry periods is essential to maintain this ground cover

Bastin G (2014) *Australian rangelands and climate change – fire*. Ninti One Limited and CSIRO, Alice Springs

- Greater summer rainfall may increase grass biomass and hence fire risk, however increasing rainfall variability will likely require two or more wetter years to build up enough biomass to support a large wildfire
- Hotter temperatures will extend the fire season, and lead to larger wildfires, particularly after successive wetter years. This will reduce the window for prescribed burning, and require more intensive focus over a shorter time in preparation for the fire season

- Further spread of Buffel grass will increase the fire risk, and may reduce the amount of rain required to initiate a growth response and subsequent wildfire (i.e. from two wet years to one wet year)
- Fire within desert spinifex areas follows substantial and extended periods of rainfall. Fires will not re-burn these areas until sufficient grass has accumulated again as fuel (i.e. 5+ years for spinifex depending on the post-fire vegetation that grows)

The average, minimum and maximum percentage areas of bioregions burnt within Rangelands Cluster NRM regions between 1997 and 2012. Data are adapted from burnt-area statistics supplied to ACRIS by WA Landgate.

SA: Alinytjara Wilurara

	Mean (%)	Min (%)	Max (%)
Central Ranges	7.5	0.1	25.8
Great Victoria Desert	1.6	0.0	6.6
Nullarbor	2.0	0.1	3.4

This table taken from the report indicates the Central Ranges is much more highly variable in terms of fire extent. It also has experienced much larger areas being burnt compared with either the Great Victoria Desert or the Nullarbor (which is largely composed of fire-resistant chenopod shrubs). It also burns more regularly than either of the other bioregions. Thus fire management should be concentrated in this region.

- Reduced winter rainfall and warmer temperatures may see the present central Australian fire regime of decadal (plus) extensive fire move south into the northern parts of South Australia and the southern WA Rangelands. It may be possible to learn from fire management strategies in the Southern NT to inform fire management in the APY Lands.

Measham TG (2014) *Australian rangelands and climate change – guidance to support adaptation: Addressing climate adaptive capacity, resilience and vulnerability of people in remote and marginalised regions*. Ninti One Limited and CSIRO, Alice Springs

- Provides vulnerability assessment steps and vulnerability/resilience framework (the same as the adaptation pathways approach utilised by Eyre Peninsula Integrated Climate Change Assessment)
- Highlights the need to focus on supporting and strengthening existing resilience of rangelands communities in the longer term, while focussing on vulnerability-reducing actions in the short term to 'buy time'

Bastin G (2014) *Australian rangelands and climate change – heatwaves*. Ninti One Limited and CSIRO, Alice Springs

- It is hot and getting hotter, with more frequent and longer heatwaves in the recent past compared with the first decade of the century across the rangelands
- No weather stations within AW NRM were used for the analysis of heatwave trends, however Giles to the NW of the region shows heatwaves have become longer, particularly in recent years (2007, 2011 and 2013)

Pavey CR and Bastin G (2014) *Australian rangelands and climate change – invasive animals*. Ninti One Limited and CSIRO, Alice Springs

- Without continued systematic control, feral camels are likely to increase in the region. Due to their adaptation to desert conditions, they are unlikely to be negatively affected by climate change
- Feral horses and donkeys are likely to be minimally affected by climate change and will thus require ongoing management
- Foxes will remain widespread and may increase in abundance in in response to climate change, however dingos/wild dogs are also predicted to increase and thus may reduce fox populations to some extent if this occurs
- The distribution of cats is predicted to decline across the rangelands under climate change.
- Modelling suggests the European rabbit will become less abundant in the rangelands due to hotter temperatures, irrespective of future rainfall trends
- Management recommendation for invasive animals are essentially “do more of the same”

Bastin G (2014) *Australian rangelands and climate change – meteorological drought*. Ninti One Limited and CSIRO, Alice Springs

- Drought will continue to be a recurrent feature in the rangelands, and is likely to increase with increasing rainfall variability
- The AW NRM region was not included in this study as it was not considered a primarily pastoral region
- Nevertheless, a key adaptation response for the pastoral industry within the AW region is simply to be prepared: utilise reliable climate forecasting services and implement drought management strategies promptly as key dates or trigger points for decision making are reached

Pavey CR (2014) *Australian rangelands and climate change – native species.* Ninti One Limited and CSIRO, Alice Springs

- The three groups that have been modelled to be most impacted by climate change are plants, snails and reptiles; impacts on mammals will be moderate, whereas impacts on birds and frogs will be low

- Future climate refugia within the AW NRM region include the APY Ranges and the Nullarbor. No-regrets strategies could focus on these areas for conservation management regardless of future change

Bastin G, Stokes C, Green D and Forrest K (2014) *Australian rangelands and climate change – pastoral production and adaptation*. Ninti One Limited and CSIRO, Alice Springs

- Maintain perennial pasture cover – perennials respond more quickly to rainfall (and help to infiltrate rain and reduce losses due to erosion and evaporation)
- Current best-practice rangeland management will be necessary, but ultimately not sufficient in the longer term to adapt to climate change – transformational change will be required
- Hotter temperatures will place greater emphasis on human safety and wellbeing and animal welfare, and these may need to be planned for and incorporated more into station management practices
- Dependable water supplies will become even more critical, and water supplies will need to be checked more often and repaired quickly if there are any problems
- A range of management techniques and responses to address climate change impacts are suggested as an Appendix to this report

Bastin G (2014) *Australian rangelands and climate change – rainfall variability and pasture growth*. Ninti One Limited and CSIRO, Alice Springs

- In the north of the AW region, where land can be maintained in good condition (i.e. where there is perennial ground cover), >25 mm events should produce a limited growth response and >50 mm events an ideal response for pastoral production. However, these larger events are infrequent, and 60% of years since 1950 (to 2012) failed to receive such rainfall
- Cook, on the Transcontinental Railway, is in the Nullarbor region where large rainfall events are very rare (median return period of almost two years for >50 mm events and 80% of recent years not experiencing such an event). The vegetation has obviously adapted to persist under such low rainfall, and cool moist days in winter (e.g. >10 mm of rainfall) can apparently produce useful new leaf growth on chenopod shrubs. Medium-sized events (>25 mm) will likely produce a herbage response by annual species, particularly in the cooler months

Bastin G (2014) *Australian rangelands and climate change – remotely sensed ground cover*. Ninti One Limited and CSIRO, Alice Springs

- Bare soil thresholds (using MODIS satellite imagery) for the Great Victoria Desert Region should be 70% in mid-March (i.e. 30% groundcover or less), for the Nullarbor this value should be 50-59.9% (i.e. 50-40% groundcover). For the Central Ranges, this value in mid-September should be 60-69.9% (i.e. 40-30% groundcover)

Appendix 2 Summary of themes of current local community concerns and other observations based on workshops conducted in 2011 and 2014

Themes	**Yalata**	**Ernabella**	**Kenmore Park**	**Mimili** (Lorna Dodd)	**Kanpi-Nyapari**	**Amata**	**Kalka-Pipalyatjara**	**Watarru**
Dates of workshops	24/6/2014	21/7/2014 & 22/7/2014	23/7/2014		22/3/2011, & 24/7/2014	21/3/2011	23/3/2011	24/3/2011
Buffel grass	Buffel grass has been observed in the community recently, and is spreading along road and rail lines	Buffel grass is damaging bushfoods – kangaroos don't eat it, it has harmed emu, malleefowl People are allergic to Buffel grass	Buffel grass is destroying native plants and bushfoods It is most widespread to the north of the community	Buffel in Victory Creek keeps spreading, despite attempts at control	When there is no Buffel they find small herbs and grasses, but Buffel destroys these plants which kangaroos and other animals eat Buffel is around the community, but not yet established out on country as much	Buffel is widespread in the area	Buffel grass makes the kangaroos sick Buffel grass is pushing into spinifex country, and burning much hotter so nothing else grows	Buffel grass is mainly along the roads, not as much on country, and also around the community. Control measures such as burning and grading are failing to manage it. It has greatly increased the fire risk around the community
Fire management	A lack of shed tanks and other resources prevents adequate fire management, particularly in the north of the Yalata IPA	Firefighting resources and training are lacking, resulting in recent damage to infrastructure Prescribed burning needs more funding to adequately cover the region	While cattle control grass to some extent to prevent large wildfires, a fire has come very close to the community and was only stopped by a grader	Smoke from nearby recent wildfires has impacted on health in the community	There is not enough burning to reduce fuel loads Fire burns in the hills near Nyapari, but not so much near the community	Timing of burning is not always correct, with too little burning at times, and then too often. Firebreaks are not maintained	Buffel grass is causing larger, hotter fires. Control burning to prevent large wildfires is not happening as much as it did in the past	People aren't walking country as much anymore, so there is less traditional patch burning
Grazing of livestock	There has been discussion about res-starting grazing on the old sheep stations but nothing has eventuated yet	Cattle are damaging ecosystems through overgrazing and spreading Buffel grass, and preventing fires being burnt to control Buffel	Land to the north, east and south of Kenmore Park is overgrazed by cattle – they are damaging country		-	Cattle with hard hooves are increasing wind erosion	-	-

Themes	Yalata	Ernabella	Kenmore Park	Mimili (Lorna Dodd)	Kan̲pi-Nyapar̲i	Amata	Kalka-Pipalyatjara	Watarru
Bushfoods / biodiversity conservation	Kangaroos have been hunted out of the local area – people have to travel a long way to hunt them Wombats are still plentiful in the region	Kangaroos have gone far away. Wildfires, camels, cattle and Buffel have reduced bushfood availability in the region Conservation priorities should be to the northeast where there are more trees and bushfood	The community wanted an IPA to the north but the country has been damaged too much by cattle There are Quandong around but they need to be monitored for camel impacts People have to go a long way to hunt kangaroo – there's not many around now		There are only a few kangaroos around, compared with the old days. There are no emus left. Quandong have been eaten by camels, a few plants in the ranges are still left	Kangaroo have disappeared from around the community. Warru (black-footed rock wallaby), possums and other animals have been killed by cats, foxes and dingos.	People have to travel 70-80km to find kangaroos to hunt There are only two warru in the hills behind the town, but lots of Euro	No kangaroos within 30km of town. Programs to provide artificial watering points for kangaroos, emu and other bushfood were supported, but there was no ongoing funding for them
Heatwaves	Heatwaves have led to power failures in Yalata community, and the whole community has been evacuated to stay in a hotel due to blackouts in the past	The rockholes north of Ernabella are no longer able to be used for cooling down People migrate to Pt Augusta or Adelaide to escape the heat Recent heatwaves have killed kangaroos (51°C)	Air-conditioning failed during the last heat wave. Healthy people leave the community to somewhere cooler, but the sick people have to stay even when it's hot	Mimili has a swimming pool which allows the community to cool down during heatwaves	Two years ago when it was very hot and not much water was left a lot of the animals died – birds, other animals and even camels The community can't swim during summer school holidays because the teacher goes away	There have been more extreme heatwaves in recent years		
Water management	Yalata groundwater supplies are declining due to over-extraction	Recent floods washed the road away behind the store and damaged the clinic.	Some roads were cut off during recent floods as the community is in a low-lying area	Local rockholes appear to be stable even in drought years, however camels	Flooding cut Nyapar̲i off from the store at Kanpi – they had to drop food by helicopter	Flooding has had some impacts, with some roads being cut and eroded	Floods cut off the town, but didn't cause much damage. There wasn't a food truck delivery for 4 weeks and a plane couldn't land because	Flooding cut off road access to the store, and supplies became very low

Themes	**Yalata**	**Ernabella**	**Kenmore Park**	**Mimili** (Lorna Dodd)	**Kanpi-Nyapari**	**Amata**	**Kalka-Pipalyatjara**	**Watarru**
Water management continued		Food had to be flown in People in homelands were stuck and couldn't come back for weeks Donkeys and camels drink and foul rockholes	Groundwater levels are dropping due over-extraction and use by cattle	drink and foul the water			the airstrip was underwater	Rockholes near the roads are maintained to hold water, but camels keep dying in the waters and messing things up Many of the rockholes further away from the roads that elders knew about and used to manage aren't being maintained now
Feral animals	Foxes and cats are an issue, however dingos control them to some extent	200 camels entered the community a few years back Horses and donkeys are a problem too. Cats and foxes eat small marsupials	Cats and foxes are destroying native animals	Significant number of camels and horses around the community	Camel mustering should happen to provide the community with an income The camels have been damaging water holes for a long time Foxes have been a problem, eating warru and birds	Camels and cats are the big problem, donkeys, rabbits, horses….Camels have been a big problem in the drought before 2011, damaging community infrastructure looking for water	Camels have caused significant damage to community infrastructure, as well as bushfoods such as Quandong. Camels need to be mustered or culled	Camels have damaged claypan vegetation by churning up the mud. They have killed all the Quandongs in the local area
Coasts	Storm surges have inundated low-lying campsites in the past Changing ocean currents and temperatures have led to unusual fish and other marine species appearing							

Appendix 3

Procedure for developing community climate change adaptation plans

Documentation of Stream 1 community engagement and analysis

Introduction

The process of community engagement utilised in the Stream 1 NRM Planning for Climate Change project is outlined below. It is important to note that this project followed on from previous work over 4 years in the AW NRM region, and both researchers conducting the community engagement had previously been to and worked on the APY Lands. As such, there has been a relatively long period of relationship- and trust-building over this time, which has helped to facilitate the engagement and workshops undertaken in this project. Past workshops in 2011 also discussed climate change impacts within communities in the APY Lands, and led to communities identifying important issues and potential projects, including opportunities for monitoring. These issue-based workshops allowed us to identify key fields to focus more recent spatially explicit analyses of likely climate change impacts and adaptation responses. It also allowed us to develop ideas on potential roles for community-based monitoring of environmental change across the region.

For future engagement with the communities that were not involved in this project, trust-building and knowledge sharing over time will be essential to develop accurate and meaningful adaptation options, rather than just fly-in/fly-out consultancy. This documentation is provided to support AW NRM staff, who already have a long working history and good relationships with communities, to be able to conduct these workshops and analysis in-house, and to embed the findings into the AW NRM organisation.

1. Literature review

Conduct a literature review of likely/potential climate change impacts for the local community/sub-region, which can be separated into different sectors (e.g. fire, water, grazing etc). In this case, and as introduced above, the review of the literature was supplemented by long-term engagement with the region and previous projects that had involved a climate change vulnerability assessment, community workshops and key stakeholder interviews.

2. Workshops

2.1 Conduct discussions with communities about current issues which may be impacted by climate change. Discussions can again be grouped into themes (e.g. fire, feral camels, buffel grass, water – flooding, groundwater, rockholes, heatwaves, bushfood etc.). Use large (A0) maps and coloured sticky dots (colours correspond to discussion themes), then write numbers on the dots and match these to notes being taken about the discussion so that notes can be related to places on the map. Take a photo of the map for later analysis. Questions could include:

- Where are current problem areas where there are lots of camels/buffel/cattle?
- Where do the big fires come? Where do people do burning to prevent these big fires?
- Is there any flooding around the community? Where does it normally flood?
- Where are areas that need to be protected for important bushfoods?
- What do people do during heatwaves? How do old people cope?

- Are there any rockholes that are drying up too quickly? Where is the general location of these? (Don't need exact location for cultural privacy)
- Are there any important rockholes that stay full for a long time? Where is the general location of these? (Don't need exact location for cultural privacy)

2.2 Conduct discussions with communities about seasonal changes they are noticing; what they look for as signs of change in the weather/seasons, what is different from when they were children. Separate men's and women's groups may be useful. Use a large (A0) seasonal calendar as the baseline, then use post-it notes to write people's observations down and put them at the appropriate time in the year, change the names or timing of seasons if necessary, and write when important events occur (e.g. Seven Sisters constellation appearing). Take a photo of the calendar for later analysis. Questions could include:

- What do you look for to tell you that the seasons are changing?
- Are there certain plants or animals that tell you when the seasons are changing? Where are these located on the map?
- What about the stars? E.g. kungkarangkalpa/Seven Sisters. Are there any other stars you look for to tell the changes in the weather/seasons? When do these happen?
- Have you noticed any differences in plant / animal behaviour since when you were children? E.g. are lizards coming out earlier? Or plants are flowering earlier? If so, which ones have you noticed are changing? Where are these located on the map?
- Which plants or animals would you like to monitor and keep an eye on? Where are these located on the map?

<u>Lessons learned from workshops</u>

- Location of the workshop is important – make sure it is undercover but also where people are comfortable sitting
- It may be useful to conduct mixed (men and women) group discussions in the first instance, but then have separate men's and women's discussions, particularly for the seasonal calendar
- Use graphics and images rather than words where possible
- Don't introduce a new topic called "climate change" with no background – start the discussion about local seasons and signs and what people are noticing, then relate this to what scientists are saying about future change
- The words/language is important – talk about 'seasons' and 'signs' and 'changes' rather than 'climate change'
- Follow up visits and longer workshops are essential for gaining trust and exploring concepts more deeply, and to give people the time to think things through
- Bring along something to give (e.g. booklet of likely local climate change impacts) in a process of mutual exchange

3. Analysis

Input all workshop points derived from step 2.1 into GIS software. Then, together with other spatial data (see list below), identify key areas of overlap between workshop data and other spatial data. Examples could include areas of perennial vegetation decline and reports of bushfood decline in these areas (or conversely areas where perennial vegetation and bushfood are still abundant), or areas that are under threat from cattle where groundwater-dependant vegetation exists with no fire history (indicating stable long-lived carbon assets). Create a new data layer which spatially identifies these areas, and group these into themes used in the workshop discussions.

Spatial data used for GIS analysis included:

- BoM 30 year rainfall average
- BoM rainfall variability
- BoM rainfall seasonality (i.e. May-Sep and Oct-Apr)
- Climatic overlays (showing broad climate zones)
- Stock infrastructure (e.g. yards, water points)
- Monitoring locations (e.g. photopoints)
- Fire scar history
- Surface water assets + risk analysis
- Groundwater assets + risk analysis
- Groundwater dependant ecosystems (both surface and sub-surface)
- Persistent green index (indicating active photosynthesis)
- Aerial imagery
- Invasive species projected future distributions (Stream 2 modelling work)
- Aerial imagery analysis of long-term woody vegetation loss
- Land-use classification
- IPAs and other reserves
- Vulnerable species distributions
- Digital elevation model
- IBRA regions
- Stream 2 boundaries
- Major and minor roads and towns/communities/homelands
- Native vegetation coverage
- Coastal features (e.g. campsites, swamps)
- Biodiversity corridors (e.g. East Meets West)

4. Feedback

Develop appropriate tools (e.g. community handbooks, short films, large seasonal calendar posters) to give back to communities and discuss whether these products accurately reflect what was said in the workshops – or if things need to be changed. Once approved, the identified areas then become the adaptation response priorities for future management.

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