SOUTH AUSTRALIA

Buffel Grass Strategic Plan

2019–2024

Government of South Australia

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Edited by: Troy Bowman, David Cooke and Ross Meffin, Biosecurity SA (Department of Primary Industries and Regions South Australia).

Contributors:

Tim Reynolds, Ben Shepherd (editors 2012 Strategic Plan).

Mark Anderson, Brett Backhouse, Doug Bickerton, Troy Bowman, David Cooke, Dwayne Godfrey, Kym Haebich, Michaela Heinson, Paul Hodges, Amy Ide, Susan Ivory, Rob Langley, Glen Norris, Greg Patrick, John Read, Grant Roberts, Ellen Ryan-Colton, Andrea Schirner, Carolina Galindez Silva, Jarrod Spencer, Clint Taylor (Buffel Grass Taskforce).

Cover photo: Dense buffel grass infested hills and plains near Umuwa, APY Lands, Troy Bowman, PIRSA

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Foreword

Buffel grass can affect biodiversity, natural and cultural heritage, communities and infrastructure. Through changes in vegetation structure and the loss of native flora and fauna, it can transform rangeland landscapes. By degrading the environment it can threaten natural, Aboriginal and European cultural heritage; remote communities and infrastructure can be impacted through the increased risk of bushfire.

South Australia took the lead in 2015 as the first jurisdiction in Australia to declare buffel grass under its weed management legislation. Our response to buffel grass in South Australia requires a delicate balance between its use as a pasture grass across state and territory boundaries, and the need to protect our environment, cultural landscapes and infrastructure.

The South Australian Buffel Grass Strategic Plan for 2019–24 presents a coordinated statewide approach to buffel grass management, building on the success of the 2012–2017 plan and further developing the existing zoning scheme and management strategies.

Primary Industries and Regions SA, through its Biosecurity SA division has facilitated the development of this Strategic Plan with input from local communities, regional boards, industry bodies, staff of other South Australian government agencies and researchers.

We are fortunate that many areas of South Australia remain free of buffel grass, and while management of buffel grass will continue in the northern rangelands, a strategy to reduce its spread can protect other valuable areas such as the Flinders Ranges.

The negative impacts of buffel grass in South Australia can be minimised through a collaborative approach between land managers, industry, traditional owners and the broader community making responsible decisions about how they maintain their environment.

Contents

Acronyms

AMLR NRMB	Adelaide and Mt Lofty Ranges Natural Resources Management Board
APVMA	Australian Pesticides and Veterinary Medicine Authority
APY Lands	Anangu Pitjantjatjara Yankunytjatjara Lands
AW NRMB	Alinytjara Wilurara Natural Resources Management Board
BHA	Bush Heritage Australia
Biosecurity SA	Biosecurity South Australia, Primary Industries and Regions SA
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEM	Department for Energy and Mining
DEW	Department for Environment and Water
DPTI	Department of Planning, Transport and Infrastructure
EP NRMB	Eyre Peninsula Natural Resources Management Board
GVD	Great Victoria Desert
MT Lands	Maralinga Tjarutja Lands
NRMB	Natural Resources Management Board
NY NRMB	Northern and Yorke Natural Resources Management Board
PIRSA	Department of Primary Industries and Regions South Australia
SAAL NRMB	South Australian Arid Lands Natural Resources Management Board

1 Executive Summary

Buffel grass (*Cenchrus ciliaris* and *Cenchrus pennisetiformis*) has been listed among species of 'extensive continental distribution' that are 'capable of destroying' Australian ecosystems (Humphries *et al.* 1991). Buffel grass is arguably the single biggest invasive species threat to biodiversity across the entire Australian arid zone, and without active management it will continue to invade a wide range of native habitats to the extent that it could replace many native species in those habitats.

Buffel grass is a perennial tussock grass native to Africa, India and Asia. Since its introduction into central Australia last century for dust control and livestock production, buffel grass has spread widely across many new landscapes causing significant problems. Although it has been planted for livestock production in other states, productivity of buffel grass dominated pastures can decline in the longer term, particularly in arid areas such as northern South Australia.

Buffel grass forms dense monocultures, increases the frequency and intensity of fires, and displaces native plants and the animals that depend on them, including bush foods and many culturally significant species. It imposes economic costs through the need to manage fire risk, and to protect biodiversity, Aboriginal culture and infrastructure. Accounting for these factors, a state-level risk assessment has determined the weed risk posed by buffel grass to be very high for both grazing rangelands and native vegetation in South Australia.

In South Australia buffel grass is now widely distributed across northern regions as populations of varying size, with extensive infestations in the far north-west. Once established, there is no single control method available for the successful management of buffel grass over extensive areas. Buffel grass has several qualities that enable it to survive and persist in arid conditions. In addition to prolific seed production and opportunistic germination, buffel grass accumulates carbohydrates at the base of its stems for slow release when needed, and has a deep root system that enables it to access water supplies faster and for longer than most native herbs and forbs. Individual tussocks have long lifespans and can readily re-sprout following fire. As a result of these traits and the extensive distribution of buffel grass, the feasibility of its containment has been risk assessed as low in native vegetation and negligible in grazing rangelands.

As such, in line with the South Australian Weed Risk Management Guide, the focus of this strategy is to reduce the overall economic, environmental and/or social impacts of buffel grass through targeted management, and to prevent spread of the weed species to key sites and assets of high economic, environmental and/or social value. In a state-wide context, with buffel grass primarily established in the north, this means protecting key environmental assets and attempting to minimise broad-scale impacts in infested regions, and preventing range expansion southwards into uninfested areas.

At a finer scale, management of buffel grass may include the destruction of localised infestations where feasible and strategically important. The potential success of management is higher if buffel grass is controlled during the early stages of invasion. A range of management options may be considered, and success will be greatest is these can be implemented in a coordinated and sustained manner at a broad scale. It is vital that decision making be evidence-based and outcomes-focused.

The strategic approach to the management of buffel grass across the state is based on three management zones: the far north-west (Zone 1); the far north, north-east and upper mid-north (Zone 2); and the far-west, lower mid-north and south (Zone 3). The aim, state-wide, is to contain buffel grass and reduce its impact. This will be achieved through the Plan's four goals:

- Goal 1 - Exclude the entry of buffel grass into SA and prevent its movement within the state
- Goal 2 - Manage impacts of buffel grass in Zone 1
- Goal 3 - Protect priority assets from buffel grass in Zone 2, and destroy infestations in Zone 3
- Goal 4 - Build capacity to manage buffel grass.

Significant partnerships and resourcing are required to work towards achieving the four goals of this Strategic Plan. Cooperation, commitment and funding are sought from industry, community and government stakeholders at the local, regional and state levels to manage this weed.

2 Introduction

Buffel grass (*Cenchrus ciliaris* and *Cenchrus pennisetiformis*) is a perennial tussock grass native to Africa, India and Asia. Since its introduction into central and northern Australia for pasture improvement and dust control, buffel grass has spread widely. It has been identified as a 'transformer weed' of the Australian rangelands (Bastin *et al.* 2008) due to its ability to fundamentally alter ecosystem structure and function.

Buffel grass is widely distributed across northern arid South Australia with infestations varying widely in size and density. Most known large infestations occur in the far northwest of the state and along roads. However, much of the land where buffel grass is likely to occur is remote and difficult to access. The actual distribution of buffel grass is likely to be wider than is currently known, and its distribution is expanding.

Cenchrus ciliaris, buffel grass.

Cenchrus ciliaris has highly varied morphological and physiological characteristics, resulting in adaptation to different climates and habitats. Many forms of buffel grass have been imported to Australia from across its native range; programs of pasture introduction have brought in approximately 580 accessions, with many informal and formal releases in central, tropical and sub-tropical Australia (Hall 2000). In addition, there are at least three other exotic *Cenchrus* species that have naturalised in South Australia and which could expand their distributions, including *Cenchrus pennisetiformis*, also called Cloncurry buffel grass. For the purposes of declaration under the *Natural Resources Management Act 2004* (NRM Act), buffel grass includes both *C. ciliaris* and *C. pennisetiformis*. Modelling suggests over 60% of mainland Australia is suitable for buffel grass establishment (Lawson *et al.* 1994). This is likely in large part due to the genetic diversity of buffel grass present in Australia.

Buffel grass is considered one of Australia's worst environmental weeds (Humphries *et al.* 1991). Many of the attributes which contribute to the success of buffel grass as a pasture species also make it a serious environmental weed. These include ease of establishment, rapid growth rate, fast maturation, prolonged flowering periods, prolific production of easily dispersed seeds with considerable seed bank longevity (Franks 2002). Buffel grass is tolerant of drought, fire and grazing. It can generate positive fire invasion feedbacks in central Australian woodlands (Miller *et al.* 2010) and has been shown to affect fire regimes in native plant communities (Butler and Fairfax 2003). It has a wide climatic tolerance and establishes on a range of soil types under a various disturbance regimes, quickly forming self-sustaining populations (Franks 2002).

Buffel grass is recognised as a major threat to country – the term commonly used to explain the land or waters with which an Aboriginal person, persons, community or homeland family has a traditional or contemporary association. This is particularly the case within the Alinytjara Wilurara Natural Resources Management Region (Alinytjara Wilurara NRM Board 2011) where buffel grass infestations are most extensive.

The perceived value of buffel grass for livestock production is offset by its serious environmental and social impacts. Furthermore, there is growing evidence that it may be nutritionally inadequate for adult dry stock and could lead to pasture degradation in the long term (NRM SAAL 2017).

Despite these challenges, South Australia clearly has an opportunity to continue to implement a strategic management approach to the weed to prevent or mitigate its impacts. Extensive areas of the state, such as the Great Victoria Desert bioregion, are still largely free of buffel grass. To maintain and build on the gains made under the previous State Buffel Grass Strategic Plan 2012–2017, and prevent buffel grass from becoming a dominant feature of our arid landscapes, significant ongoing management intervention will be required.

This plan guides state level prioritisation and coordination to deliver a strategic approach to buffel grass management, as well as development of regional weed management plans. Partnerships are required to find solutions to the conflicting perceptions of buffel grass among stakeholders, and resource communication, extension, on ground activities and applied research to fill remaining knowledge gaps.

2.1 Strategic plan development

The 2012–17 Buffel Grass Strategic Plan was based on a draft State Operational Plan that was prepared following a workshop held in Port Augusta in September 2010. The aim of the workshop was to initiate and guide the development of a state-wide strategic approach to minimising the impacts of buffel grass in South Australia. The workshop was instigated by Biosecurity SA with support funding from the 2010/11 State NRM Program,

and involved representatives of state agencies (PIRSA, DEWNR, DPTI), regional NRM Boards, and research organisations (CSIRO, University of Adelaide).

The current updated plan was prepared by the SA Buffel Taskforce in consultation with the key stakeholders identified in section 3.4. It recognises the important outcomes achieved through the first iteration of the plan and aims to sustain and build upon these. Achievements aligned with the 2012- 2017 plan were mostly delivered through a project funded by the Native Vegetation Council with supporting contributions from NRM Regions and PIRSA: the Buffel Grass Control in Arid Rangelands project. These included:

- strategic control of over 300ha of buffel grass outlier infestations
- herbicide research and a report identifying best practice options for control
- five fact sheets developed to communicate best practice management
- over 4,600km of roadsides surveyed, documenting distribution and spread of buffel grass
- a GIS distribution database and control prioritisation tool
- community engagement activities involving well over 270 stakeholders
- awareness building through media articles and interviews
- technical advice to stakeholders throughout South Australia and nationally

Despite this, much remains to be done. The Buffel Grass Control in Arid Rangelands project made a number of recommendations to guide future buffel management. These are summarised below, and further details can be found in the project final report (available at pir.sa.gov.au/buffel-grass):

- continuation of the SA Buffel Grass Taskforce and pursuing options to fund a dedicated buffel grass coordinator
- further engagement of a range of stakeholders including the mining industry, road and rail corridor managers, National Parks rangers and pastoralists
- annual strategic responses to target key on ground works and support capacity and coordination at regional level
- follow-up surveillance and control in areas treated through the 2015 and 2016 strategic responses, and in key dispersal nodes such as Port Augusta and Coober Pedy
- surveillance and mapping to identify priority infestations for control and improve understanding of buffel distribution.

With best practice materials developed and a range of control options to suit most situations, future activities will be refocussed to fill gaps identified during the process of updating this plan. Key challenges include improved and expanded stakeholder engagement, maintaining funding and momentum for on-ground action and containment, better mapping and knowledge of distribution, and developing strategies and tools for managing buffel grass in remote areas with widespread, extensive infestations.

This strategic plan will be reviewed in five years (2024). In addition, an update of legislative aspects of the plan (particularly section 2.5) will be required following the replacement of the NRM Act by the *Landscape South Australia Act*, currently planned for mid-2020.

Aerial herbicide trial, Mambray Creek.

2.2 Principles underpinning the Strategic Plan

The following principles underpin this strategic plan:

1. Weed management is an essential and integral part of sustainable management of natural resources and the environment and requires an integrated, multi-disciplinary approach
2. Evidence-based decision making should underpin weed management activities
3. Prevention and early intervention are the most cost effective techniques that can be deployed against weeds
4. Successful weed management is a responsibility shared among landholders, community, industry and government and coordination amongst these stakeholders is essential to manage weeds at a landscape scale.

2.3 Taxonomic scope of Strategic Plan

The main focus of this Plan is the management of *Cenchrus ciliaris* in South Australia, due to its current and potential impact. However, three other exotic *Cenchrus* species with weed potential and the ability to expand their current distribution in the state are also noteworthy. *Cenchrus pennisetiformis* is declared along with C*. ciliaris* as buffel grass under the NRM Act, and is within the scope of the plan. *Cenchrus setiger* and *Cenchrus echinatus* have restricted distributions and are not declared. However, in keeping with principle three of this plan, consideration should be given to prevention activities, i.e. the early detection of incipient populations and rapid response to prevent widespread establishment. This could likely be achieved opportunistically alongside buffel grass management.

2.4 Linkages to other plans

National

This strategic plan is consistent with the vision of the Australian Weeds Strategy, to '*protect Australia's economic, environmental and social assets from the impacts of weeds*', and in particular Goal 2: *Minimise the impact of established weeds*.

State

Priority element 3 of the State Biosecurity Policy 2017/2021 is relevant to buffel grass: *Minimising the economic, social and environmental impacts of pests and diseases, - in particular, developing and implementing management plans and programs to contain spread and reduce the impacts of established priority pests and diseases.*

Section 4(b) (ii), an Object of the *Pastoral Land Management and Conservation Act*, 1989, is the legislative basis of the aforementioned policy. This Object provides for "the prevention of degradation of the land and its indigenous plant and animal life".

Regional

Buffel grass is recognised in regional pest management strategies for the AW, EP, SAAL and SAMDB NRM Boards, including the *Alinytjara Wilurara Buffel Grass Operational Strategy 2018-2023*.

Buffel grass is noted for its impact on threatened species in the Threatened Species Recovery Plan, and the Rare and Threatened Flora Management Plan, for the APY Lands (Paltridge *et al.* 2009).

Species	Description	Comment
C. pennisetiformis (Buffel/Cloncurry grass)	Perennial grass, easily confused with *C. ciliaris*	Used for pasture in Australia. Appears to have similar invasive properties as *C. ciliaris*. Few herbarium records for SA (< 15: Flinders Rgs & Far North) – may greatly under-estimate its true prevalence.
C. setiger (Birdwood grass)	Perennial grass, similar to smaller types of *C. ciliaris*	Has been planted for pasture in Australia. Adapted to a wider range of soils and more drought tolerant than *C. ciliaris*. A serious weed of watercourses in WA. Only three records for SA (far NW).
C. echinatus (Mossman River grass)	Annual grass, clump-forming, spiny attachable burrs	Not deliberately cultivated in Australia – a pest of pastures and some crops. Less than 20 records for SA (far NW incl. APY Lands).

2.5 Legislative context

Buffel grass is currently declared under the *NRM Act*, providing a legislative basis for management as specified in this strategic plan and regional NRM plans.

From late 2020, the new *Landscape South Australia Act 2019* will become fully operational and will replace the NRM Act. The Landscape South Australia Act continues to provide for the control of weeds, including through some improved and simplified provisions. Buffel grass will remain a declared weed, and this plan will remain relevant in its intent and utility as a high-level strategic document.

The following provisions of the NRM Act apply:

Currently no other Australian states or territories have regulated the management of buffel grass under their respective legislative frameworks. However, it is unclear what actions are required under a 'general biosecurity duty of care' system such as is in effect in Queensland and New South Wales. In New South Wales buffel grass is included in the key threatening process listed under the *Threatened Species Conservation Act 1995*, Invasion of native plant communities by exotic perennial grasses.

As one of the greatest single threats to biodiversity by an invasive species within the Australian arid zone, buffel grass was nominated as a Key Threatening Process under the terms of the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Although it was considered that this is already recognised in the overarching key threatening process 'Novel biota and their impact on biodiversity', the nomination resulted in the issuing of a threat abatement advice (Department of the Environment 2015).

Section	Requirement	Control Area
75(1)(2)	Prohibiting movement on public roads and entry into SA	Whole of state
177(1)(2)	Prohibiting sale of the plants or their seeds, or contaminated material	Whole of state
180(1)(2)(3	Requires landholders to notify the presence of buffel grass on their land	The areas of the Kangaroo Island, South Australian Murray-Darling Basin, and South East NRM Regions.
182(1)	Requiring landowners to destroy the plants on their properties	The areas of the Adelaide and Mount Lofty Ranges, Eyre Peninsula, Kangaroo Island, South Australian Murray-Darling Basin, and South East NRM Regions
182(2)	Requiring landowners to control - as far as reasonably achievable - the plants on their land	The areas of the Alinytjara Wilurara, Northern and Yorke, and South Australian Arid Lands NRM Regions
185	NRM authorities may recover certain costs from owners of land adjoining road reserves	Whole of state

The associated declared plant policy can be found at pir.sa.gov.au/buffel-grass

Rocky hill with pristine *Triodia* grassland.

Rocky hill heavily invaded by buffel grass.

3 Strategic Goals and Actions

3.1 Vision

Buffel grass is no longer spreading throughout South Australia, and through increased awareness and action the impacts of buffel grass are minimised, especially at sites of environmental, cultural and economic significance.

Case study:

Buffel Grass Program on Bon Bon Station Reserve

Bon Bon Station Reserve, a former sheep station south of Coober Pedy in South Australia, is owned and managed by Bush Heritage Australia (BHA) as a private conservation reserve. The 217,000 ha reserve is managed to protect ephemeral wetlands and surrounding western myall (*Acacia papyrocarpa*) and mulga *(Acacia aneura)* woodlands and chenopod shrublands associated with Lake Puckridge. Buffel grass threatens the woodlands and shrublands through changed vegetation structure and increased fire risk.

The buffel grass control program is currently focused along the old and new alignments of the Stuart Highway, a total distance of 130 km. Movement of vehicles along the transport corridor is the main vector for the spread of buffel grass seeds throughout the reserve.

Additionally, there are a few drainage lines that are being actively managed to eliminate the threat of these sensitive systems becoming severely infested with buffel grass.

Our strategy

A buffel grass management strategy has been developed and is being implemented. A key focus of the strategy is to progressively reduce buffel infestations from the relatively clean north and eastern parts of the reserve, working south and west. This strategy was initiated in 2013 and it was estimated it will take four-five years to do initial treatments while undertaking annual control of regrowth.

Funding for the work has come from Bush Heritage Australia, an environmental grant from the Native Vegetation Council as well as additional support from the South Australian Arid Lands Natural Resources Management Board (SAAL NRM) and the Department of Planning, Transport and Infrastructure (DPTI).

Fire was also used to treat four sites along the Stuart Hwy road verge early in April 2014. This project was instigated by DPTI and undertaken using DPTI, Country Fire Service (CFS) and BHA resources. Four small sites were burnt over two days (as weather conditions were unfavourable).

Buffel grass on Stuart Hwy before treatment.

Same site post treatment.

Regeneration after buffel grass control.

The burning was successful at reducing dry matter and seed banks, but needed a large amount of resources (two CFS water tankers, five CFS staff, one DPTI vehicle and staff for traffic control plus BHA staff and vehicle). Following burning, herbicide was applied to all four sites.

After four years of buffel grass treatment all of the 130 km of highway verge has been treated at least once with other areas with higher infestations being treated up to five times. Surveillance for buffel grass infestations will be maintained indefinitely by BHA, especially along main transport corridors.

Challenges faced in controlling buffel grass at Bon Bon Station Reserve are the sheer size of the task, resources required and the need for a quick response during the short growing season. The development of effective control strategies beyond the growing season will greatly assist the management plan.

Key Learnings

1. Glyphosate/flupropanate mix has consistently delivered good knockdown and good regrowth control for at least two years.
2. Flupropanate alone gave mixed results on mature plants.
3. Soil applied chemicals are good for isolated detctions.
4. Fire is a very useful tool for reducing dry matter and seed banks, but requires significant resources.
5. Achieving at least 95% kill at first treatment is necessary.
6. Diligent retreatment is imperative and requires as much time as the first treatment but may only require a fraction of the herbicide.
7. To get best regrowth control with residual herbicides, complete ground spray is necessary.

Acknowledgements

Although buffel grass management on Bon Bon Station Reserve is an ongoing program, the control actions that have been undertaken to date would not have been possible without the assistance of the Native Vegetation Council, Department of Planning, Transport and Infrastructure, Biosecurity SA, South Australian Arid Lands Natural Resource Management including the Kingoonya NRM group, Country Fire Service, Roxby Buffel Busters, Friends of the Gawler Ranges, Mike Chuk and Julia Harris (BHA Bon Bon Station Reserve managers 2013-2017). A special thanks to Glenbarr weed and pest control to their dedication to the BHA Buffel grass management strategy.

Hand removal of buffel grass by volunteers.

3.2 Management zones

A key component of reducing the impacts of buffel grass in South Australia is a management strategy based on a zonal system reflecting the gradient of invasion and establishment of buffel grass from the far north-west to the southern regions of the state. Management zoning is a tool that can be used to guide planning and management at a broad scale. It does not prescribe what must occur at a local scale, which should be determined on the basis of local issues. The use of a management zone approach recognises that while management of an invasive plant depends on local actions, these will be much more effective and efficient when they are part of a broader scale strategic approach (e.g. Grice *et al*. 2011).

A state buffel grass workshop in 2010 identified a state containment line that divided the north of the state from the south at 29 degrees latitude (i.e. near the township of Coober Pedy, largely within the SAAL NRM region). Although buffel grass is well established south of this line, efforts should be made to maintain this line, both in terms of on-ground control and as a symbolic statement of intent. It should be noted that these efforts are directed at achieving benefits not only for the SAAL NRM region, but broader benefits for the state as a whole. As such, and in line with principle four of this plan, it is appropriate that resourcing these activities should not be the sole responsibility of the SAAL NRM Board, and other private and public beneficiaries should contribute where possible. It should also be recognised that there are other containment lines of state significance, such as our north-eastern borders with other jurisdictions, as well as dispersal nodes of strategic importance to the state, such as Port Augusta. Managing these too should be considered in the context of wider benefit and resourced accordingly.

In this strategic plan, management zone boundaries are delineated broadly on the basis of current knowledge of the weed's extent, having implications for the feasibility of eradication. These boundaries can be reviewed in the future as the extent of buffel grass across the state is monitored. The state weed risk assessment determined a "manage weed" management action for the 'Rangelands Grazing' land-use, and "manage weed/protect sites" action for the 'Native Vegetation' land-use. The goals for the management zones broadly align with this risk assessment.

The state management zones (Figure1) should also be considered in developing Regional Weed Management Plans for individual NRM Boards:

Zone 1 – Manage buffel grass

NRM Boards: Alinytjara Wilurara - Anangu Pitjantjatjara Yankunytjatjara (APY) Lands; SA Arid Lands - Marla-Oodnadatta NRM District.

Status: Numerous, extensive, widespread infestations, particularly in the far north-west.

Management aim: To reduce the overall impacts of buffel grass through targeted management, including protection of sites of cultural and environmental significance and control of outlier populations

MANAGE WEED

- aims to reduce the overall economic, environmental and/or social impacts of the weed species through targeted management
- research and develop integrated weed management (IWM) packages for the species, including herbicides and biological control where feasible
- promote IWM packages to landholders
- monitor decrease in weed impacts with improved management
- identify key sites/assets in the management area and ensure adequate resourcing to manage the weed species

Zone 2 - Protect sites

NRM Boards: SA Arid Lands (SAAL) excluding Marla-Oodnadatta NRM Group; Northern and Yorke - Upper North sub-region

Status: Large and small, widely distributed infestations, with some larger infestations challenging to contain or control, for example:

- townships along major roads, in particular Port Augusta, Pimba, Copley, Glendambo, Kingoonya, Tarcoola and Coober Pedy
- National Highway 1 road reserve and adjoining land between Port Augusta and Port Pirie
- the rail corridor (Interstate Main Line) between Port Augusta and Wynbring (SAAL and AW NRM)
- the North Flinders District (SAAL)
- parts of Innamincka Regional Reserve (SAAL).

Management aim: To prevent the ongoing spread of buffel grass into clean or priority areas within or beyond Zone 2, aiming for a significant reduction in all infestations.

PROTECT SITES

- aims to prevent spread of the weed species to key sites/assets of high economic, environmental and/or social value
- surveillance and mapping to locate all infested areas
- identification of key sites/assets in the management area
- control of infestations in close proximity to key sites/assets, aiming for a significant reduction in weed density
- limits on movement and sale of species within management area
- monitor change in current distribution within and in close proximity to key sites/assets.

Zone 3 - Destroy infestations

NRM Boards: Alinytjara Wilurara - Maralinga Tjarutja (MT) Lands south of the northern boundaries of Mamungari and Tullaringa Conservation Parks); rail corridor west of Tarcoola within SA Arid Lands; Eyre Peninsula; Northern and Yorke - Lower North sub-region and Yorke sub-region; SA Murray-Darling Basin; Kangaroo Island; South East.

Status: Predominantly small, widely scattered localised infestations, currently known to occur in EP, NY, AMLR, SAMDB and the MT Lands of the AW NRM Board. Not yet recorded in KI.

Management aim: To significantly reduce the extent of buffel grass in Zone 3, locating and destroying all infestations aiming for local eradication at feasible sites.

DESTROY INFESTATIONS

- aims to significantly reduce the extent of the weed species in the management area
- detailed surveillance and mapping to locate all infestations
- destruction of all infestations, aiming for local eradication at feasible sites
- prevention of entry to management area and movement and sale within
- monitor progress towards reduction.

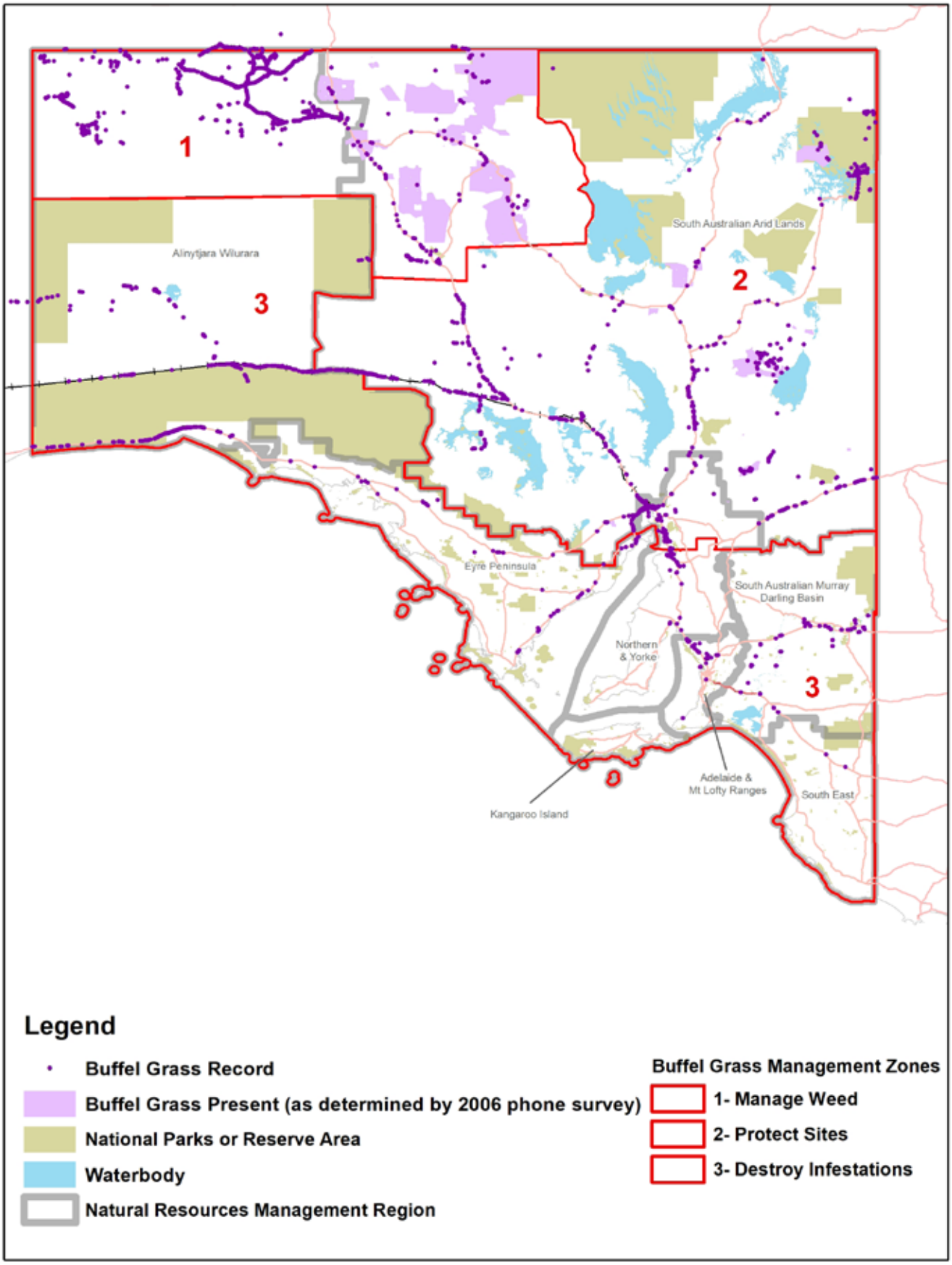
Figure 1. Buffel Grass Management Zones and records in South Australia, 2018. Note, the map displays cumulative records of buffel grass collated from a variety of sources. It does not account for infestations that are being actively controlled and the current status of each population is not known. Given known seed longevity, infestations must not have set seed within the last five years for an infestation to be considered as eradicated, therefore regular mapping and monitoring are important in producing a map showing only currently extant infestations.

The majority of infestations in Zone 3 are situated along roadsides and are subject to ongoing management. Intensive buffel grass management commenced in many regions in 2013 and if this continues it is expected that many outlier infestations in Zone 3 may be considered eradicated in 2019-2020.

Buffel grass distribution as determined by the 2006 phone survey is an indicator of presence within the parcel only, it does not provide any indication of the distribution or density contained within.

The map also contains a bias towards roadside data collection and is likely not representative of buffel grass occurrence away from roads. The actual distribution of buffel grass is likely to be much more widespread than is currently recorded in the northern half of the state due to its widespread distribution and a lack of survey data on private property and in inaccessible areas.

Buffel Grass Management Zones and Records in South Australia



Legend

- Buffel Grass Record
- Buffel Grass Present (as determined by 2006 phone survey)
- National Parks or Reserve Area
- Waterbody
- Natural Resources Management Region

Buffel Grass Management Zones

- 1- Manage Weed
- 2- Protect Sites
- 3- Destroy Infestations

Produced By: Troy Bowman
Invasive Species Unit- PIRSA (July, 2018)
Data Source: Weed data from Rural Solutions SA, DEW, DPTI, Biosecurity SA, Topo 250K from PIRSA, NRM regions and National Parks from DEWNR.

Projection: Lambert Conformal Conic
Datum: Geocentric Datum of Australia 1994 (GDA 94)

N

0 100 200 300 400 Km

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3.3 Goals and Actions

Goal 1 - Prevent

Exclude the entry of buffel grass into SA and prevent its movement within the state (all zones)

Background

Vast areas of South Australia are susceptible to buffel grass invasion and impacts. A key means of minimising the impacts of buffel grass across the state is the early detection of plants in areas where it is absent or sparse, and preventing the establishment of new populations. Priority should be given to areas where there is a significant risk of incursion and to important assets that would be threatened by establishment of buffel grass. Effort should focus on the routes by which buffel grass is likely to spread, principally transport corridors.

Industries and communities are encouraged to assist, particularly in the northern parts of the state, to prevent spread and to detect new infestations. Mining industries are users of some remote areas of the state, with movement of workers and machinery through these areas presenting risks of inadvertent spread. Any future growth in exploration, mining, petroleum or geothermal industries would need to be done in an appropriate manner to ensure the prevention of the spread and effective management of buffel grass. Earthworks such as roadside grading can spread seed, starting new infestations or expanding existing infestations. Road managers need to be aware of the risks of spreading the weed in this way and adopt appropriate hygiene practices. A range of education and awareness activities will be required including protocols to reduce seed spread, and more effective awareness campaigns. Resources need to be available when new infestations are detected to enable timely responses.

Increasing public and community awareness of what buffel grass looks like, its impacts and the benefits of control, is essential to building community willingness and capacity to prevent, monitor for, and control new buffel grass occurrences (Pitt 2004). Landholders should be provided with information regarding the negative ecological and economic effects of buffel grass, as well as restrictions and obligations under the NRM Act. Signage on roadsides, in rest stops at sites of cultural and environmental significance is an effective method that could be employed by the SAAL NRM Board to raise public awareness and reduce the risk of spread into uninfested areas.

Buffel grass hygiene is a critical component of preventing the spread of this highly invasive weed, either from interstate or within South Australia. Due to its prolific seed production, small seed size and presence of fine seed hairs, it has the ability to spread long distances via vehicles, earth moving and other machinery, stock, wind, water and other human activities.

Avoidance is the best method of reducing the potential spread of buffel grass seed so where possible people should stay on tracks and avoid driving or walking though buffel grass infestations.
To minimise the risk of inadvertent spread, members of the public should ensure vehicles, machinery and personal items are free of buffel grass seed through thorough decontamination and on-farm biosecurity measures.

For more information on buffel grass hygiene visit pir.sa.gov.au/buffel-grass

ACTION	Activities	Responsibility	Priority
1.1 Minimise inadvertent spread of buffel grass by human activity	• develop Codes of Practice with reference to containment for road and rail infrastructure managers • conduct community extension activities to promote awareness of impacts, mode of spread, hygiene and control options • public signage at strategic locations to promote awareness of the risk of inadvertent spread • work with graziers to minimise the risks associated with stock movements from infested parts of Australia to parts of SA where eradication has been declared the principal management objective	NRMBs DPTI, councils, industry	High
	• seek a cross-jurisdictional approach to preventing the further spread of buffel grass into SA from other states and territories (i.e. WA, NT, Qld, NSW) through national committees and working groups.	Biosecurity SA, NRMBs, Community, NGOs	

ACTION	Activities	Responsibility	Priority
1.2 Develop and maintain early detection and eradication mechanisms	• identify new entry pathways for buffel grass seed in SA • undertake systematic surveys to ascertain the distribution status of buffel grass in SA and across state borders, particularly along high risk spread pathways • undertake research into options to enable cost effective mapping of remote and outlier infestations.	Biosecurity SA and NRMBs	Medium

Shrubs killed by buffel grass fire, surrounded by a sea of buffel grass regrowth, APY Lands.

Goal 2 – Manage buffel grass in Zone 1

Reduce the overall impacts of buffel grass in ZONE 1 through targeted management (NRM Boards: AW - APY Lands; SAAL - Marla-Oodnadatta NRM District)

Background

Control within Zone 1 should focus first on limiting further spread. The conventional approach is to concentrate on the small, outlying patches at the edges of an infestation, working back towards the core. However, a combined approach of destroying outliers and limiting seed production in large patches may be more effective in the longer term. Building capacity for on-ground work is essential to continue to manage infestations in Zone 1.

This zone includes areas where only limited management activities are currently economically and technically feasible. These sites include dense, inaccessible infestations that may be lower priority because they are a long distance from infrastructure, key ecological assets, and/or organised management groups.

Mapping is important to determine where infestations are located, the area infested within a region, which infestations are eradicable, and where buffer/control zones should be located. Identifying priority areas for control should therefore consider:

- size and density of infestations
- distribution of infestations (isolated/scattered/widespread)
- proximity to natural and cultural assets at risk
- pathways of spread (roads, drainage lines, towns, etc.)
- accessibility.

Where resources are constrained, the need to delimit more accurately known infestations may need to be reconciled with a more urgent need to control infestations threatening Priority Assets[1].

ACTION	Activities	Responsibility	Priority
2.1 Improve knowledge of buffel grass distribution in Zone 1	• survey and map areas where buffel grass presence is unknown • undertake surveillance and mapping of key priority areas, in particular high risk pathways (e.g. roads, rail, towns) • map sources and the invasion fronts of priority infestations and determine the ongoing control requirements • maintain databases of buffel grass distribution throughout the state.	AW, SAAL	Medium
2.2 Identify and prioritise areas for management	• include buffel grass management in regional plans • liaise with Traditional Owners and pastoral lessees • identify and prioritise infestations according to proximity to Zone 2. Determine localised containment lines for larger infestations • develop criteria for prioritising other areas, including the establishment of clean areas within the core areas of infestation, and the protection of priority assets. Identify roadside and non-roadside destruction targets based on isolation and feasibility of control. Plan actions according to risk of spread. • develop and implement management plans for buffel grass on public lands • ensure buffel grass management is included in regional, industry and property planning • monitor and evaluate all management programs.	AW, SAAL AW, SAAL, DEW DEW AW, SAAL, land managers	High

ACTION	Activities	Responsibility	Priority
2.3 Contain or reduce established infestations in Zone 1 to prevent their spread into Zone 2 or 3	• treat infestations using appropriate control techniques • involve landholders and community in the control of priority infestations • regularly inspect treated areas for regrowth after significant rainfall events • provide assistance and resources for effective follow-up • record infestations treated	AW, SAAL, land managers	High
2.4 Destroy and monitor outliers, new incursions and infestations threatening Priority Assets in Zone 1 where feasible	• treat infestations using appropriate control techniques • involve landholders and community in the control of priority infestations • regularly inspect treated areas for regrowth after significant rainfall events • provide assistance and resources for effective follow-up • record infestations treated • monitor control sites to confirm eradication.	AW, SAAL, land managers	High

[1] Priority assets may be considered in the following broad categories:
- Social (e.g. cultural sites, dwellings, settlements at risk of buffel grass-fuelled fire)
- Environmental (e.g. species or ecological communities of conservation significance; specific habitats)
- Economic (e.g. native pastures and pastoral or mining infrastructure at risk of buffel grass-fuelled fire)

Buffel grass invasion in native shrubland.

Goal 3 – Protect Sites (Zone 2) or Destroy (Zone 3)

PROTECT SITES: Protect priority assets from buffel grass in ZONE 2 aiming for a significant reduction in priority infestations (NRM Boards: SAAL excluding Marla-Oodnadatta NRM Group; Northern & Yorke's Upper North sub-region)

DESTROY: Significantly reduce the extent of buffel grass in ZONE 3, locating and destroying all infestations aiming for local eradication where feasible (NRM Boards: EP, NY – Mid North and Yorke sub-regions, SAMDB, AMLR, SE, KI; AW - MT Lands south of northern boundaries of Mamungari and Tullaringa Conservation Parks)

Background

There are significant areas of South Australia that are free of buffel grass or have only scattered populations. With committed and sustained action, these areas can be protected from the establishment or further spread of the plant.

Mapping is an important first step in planning an eradication program. New infestations of buffel grass are often associated with roads, railway corridors and watercourses. Buffel grass establishes readily in these disturbed environments and human activities such as roadworks spread seeds further along these pathways from which natural dispersal into the surrounding landscape can occur. Roadside surveys may be undertaken to indicate infested and un-infested areas on a regional scale. GPS should be used for accurate mapping and sharing of data. Data collected by various sources should be collated prior to new surveys. Focusing on high-risk sites for buffel grass is one basis for planning surveys. Where resources are constrained the need to delimit known infestations more accurately may need to be reconciled with a more urgent need to control infestations threatening Priority Assets[1].

The best opportunities to control buffel grass are in areas where it is confined to transport corridors and verge areas in townships (e.g. Appendix 2). Once it disperses from these areas into the surrounding landscape control becomes significantly more difficult and costly.

Although many buffel grass infestations in Zone 2 are relatively small and isolated, there are some locations where control is likely to be more difficult. This may be due to the density, size and remoteness of the infestations, and the economic incentive to control, for example:

- townships along major roads, in particular Port Augusta, Pimba, Copley, Glendambo, Kingoonya, Tarcoola
- the rail corridor (Interstate Main Line) between Port Augusta and Tarcoola (SAAL NRMB)
- North Flinders District (SAAL NRMB)
- Innamincka Regional Reserve (DEW).

In Zone 3 where destruction of infestations is the principal management aim, enforcement of control should be considered as a last resort, with primary emphasis on encouraging landholders through involvement in weed management to provide ownership of the issues and consequent outcomes or problems.

Buffel grass invading spinifex grassland.

Controlled burn of buffel grass, Umuwa, APY Lands.

ACTION	Activities	Responsibility	Priority
3.1 Improve knowledge of buffel grass distribution in Zones 2 and 3	• survey and map areas where buffel grass presence is unknown • undertake surveys of high risk pathways (e.g. roads, rail, towns) where there are current knowledge gaps • undertake delimiting surveys of each infestation • undertake landholder surveys to identify distribution on private land.	NRMBs, DEW	Medium
3.2 Prioritise infestations for treatment	• map known infestations in Zone 3 by 2023. • determine the feasibility of eradication of these infestations • prioritise activities based on: o assets at risk (“Priority Assets”) o high risk source infestations (e.g. townships) o invasion pathways, and o isolated occurrences (e.g. Appendix 2).	NRMBs, DEW	Medium
3.3 Develop and maintain early detection and eradication capability	• establish state-level procedures for receiving and responding to reports of new infestations, including specimens in State Herbarium • improve communication and reporting networks between agencies • increase the capacity of stakeholders to recognise, detect and report new incursions - develop community surveillance networks • monitor high risk invasion pathways (e.g. roads, towns) during the growing season / undertake surveys of high risk areas following significant rainfall events.	Biosecurity SA, NRMBs, DEW	Medium
3.4 In Zone 2, protect priority assets from buffel grass aiming for a significant reduction in all infestations	• treat infestations using appropriate control techniques • involve landholders and community in the control of priority infestations • regularly inspect treated areas for regrowth after significant rainfall events • provide assistance and resources for effective follow-up • record infestations treated.	SAAL , NY, land managers	High
3. 5 In Zone 3, destroy infestations where feasible	• treat infestations using appropriate control techniques • involve landholders and community in the control of priority infestations • regularly inspect treated areas for regrowth after significant rainfall events • provide assistance and resources for effective follow-up • record infestations treated.	All stakeholders	High

Goal 4 – Build capacity

Ensure SA has the capability and commitment to manage buffel grass (all zones)

Background

Capacity building is a key part of buffel grass management, and in most of the state has been below the level required for effective management.

The current and potential distributions of buffel grass in South Australia are large: the resources required to prevent the spread of buffel grass and minimise the impacts are therefore large, and effective management of the weed requires a coordinated approach involving all key stakeholders. Management on government land, as well as on privately managed land, is required as this species occurs in protected areas and other Crown lands. Control programs are expensive and will require on-going landholder commitment to follow-up. Education activities to promote community awareness of the buffel grass threat will need to be ongoing.

Some research has been conducted on the ecological impacts and control of buffel grass, both interstate and through the Buffel Grass Control in Arid Rangelands Project. This has fulfilled the most pressing needs, but some gaps still remain. While the focus should be on stakeholder engagement and on-ground management, there is still a need to undertake targeted, prioritised research that will contribute towards improved buffel grass management in this state. Research into the economic impacts of buffel grass, alternatives to its use in productive rangelands, and options for mitigating the impacts of widespread, remote infestations should be encouraged.

The capacity of the state to manage buffel grass effectively will require the commitment and cooperation of key stakeholders in particular public land managers (DEW), road managers (e.g. councils, DPTI), Aboriginal landowners, the mining, pastoral, transport and tourism industries and the Australian Government.

Regional authorities and landowners should incorporate strategic buffel grass management in regional and local planning in accordance with this Strategic Plan. Regional planning may require the development of plans specific to buffel grass, particularly where the threat is recognised as a high regional priority.

ACTION	Activities	Responsibility	Priority
4.1 Coordinate and maintain buffel grass management at a state level	• maintain the State Buffel Grass Taskforce • facilitate the inclusion of strategic buffel grass management in pest management planning by regional authorities • seek funding for a state coordinator to coordinate control activities and deliver extension services.	Biosecurity SA, NRMBs	High
4.2 Promote awareness of buffel grass to land managers and the community	• develop a strategic communications and engagement plan to be coordinated by the Taskforce • conduct extension activities to promote awareness of impacts, mode of spread, hygiene and control options • disseminate regular updates to weed managers on the progress of buffel grass management across the state • maintain best practice management information and provide in a variety of media formats.	NRMBs Biosecurity SA	Medium
4.3 Consolidate and centralise existing distribution and control data across SA	• maintain a state database of buffel grass distribution and control	NRMBs Biosecurity SA	Low
	• make data available to NRM Boards and regional weed managers to aid in priority setting.	NRMBs Biosecurity SA	Low

ACTION	Activities	Responsibility	Priority
4.4 Guide and support research on buffel grass biology and control	Key research areas (refer Appendix 1 for further details): o ecology o impacts o taxonomy o management / control o distribution – current and potential.	Research, organisations Biosecurity SA	Medium
4.5 Develop and promote integrated weed management to maximise benefits of buffel grass control	• establish best practice demonstration sites and conduct training in management techniques • promote best practice options for buffel management and alternatives to its use.	NRMBs Biosecurity SA Universities	Medium
4.6 Actively involve land managers and the community in buffel grass management	• seek support and engagement for the management of buffel grass from community, industry and government. • establish and maintain networks with relevant agencies, groups and individuals • encourage the reporting of new infestations • investigate funding opportunities for landholder incentives • long-term capacity building for community groups.	NRMBs Land managers Community	High

Buffel grass strategic response team, Coober Pedy.

3.4 Stakeholder opportunities and challenges

Effective management of buffel grass in South Australia can be achieved with the following contributions by key stakeholders. In addition, each of these stakeholders has a general duty of care to take reasonable precautions to ensure that their actions do not harm the environment, for example by spreading a declared weed.

Australian Government

The Australian Government is responsible for the management of Commonwealth lands, including Department of Defence lands, and for the administration of the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act).

This includes:

- undertaking strategic buffel grass control on Australian Government managed lands in South Australia.
- supporting the protection of Matters of National Environmental Significance (as defined by the EPBC Act) threatened by buffel grass within South Australia through national funding programs.
- continuing to support the recognition of buffel grass under the 'Novel biota and their impact on biodiversity' key threatening process.
- continuing to support the buffel grass threat abatement advice.

Biosecurity SA (Department of Primary Industries and Regions South Australia)

Biosecurity SA provides technical, policy and scientific expertise for the control of declared plants under the NRM Act. It develops state policies, provides legislative recommendations to the Minister for Environment and Water, and works closely with NRM Boards and other stakeholders to implement policies for the management of weeds in SA.

This includes:

- reviewing current state policy and where required provide legislative recommendations to the Minister to achieve state level objectives for managing buffel grass
- contributing to buffel grass control and coordination at the state level through continued representation on the State Taskforce to complement the management and delivery of the Strategic Plan
- promoting consistency with this Strategic Plan in NRM Board regional weed management plans and future Landscape Plans
- providing advice to stakeholders on the inclusion of strategic buffel grass management, and recommended control methods, in pest management planning
- contributing to priority research initiatives
- sourcing funding for strategic management programs and research
- continuing to facilitate state level mapping.

State Buffel Grass Taskforce

The State Taskforce has provided guidance, direction and policy advice for the management of buffel grass across SA through the delivery of the Strategic Plan.

This includes:

- ensuring a diversity of community and agency views are maintained on the taskforce for effective implementation of the revised strategic plan
- advising stakeholders on strategic buffel grass management and recommended control methods in pest management planning
- continuing to monitor and evaluate the implementation of the strategy and refine as appropriate
- assisting in the support, development and implementation of programs and initiatives that deliver strategic actions
- coordinating and facilitating the exchange of information on control initiatives around the state
- reviewing and improving communication and extension plans where appropriate
- monitoring and evaluating success of the plan
- maintaining and strengthening partnerships with key stakeholders to improve strategic buffel grass management
- developing and implementing communication and extension plans where appropriate
- contributing to a greater national recognition and understanding of the threat posed by buffel grass to natural, economic and social systems
- identifying funding sources and provide independent advice for prospective applicants for projects consistent with the needs of the Strategic Plan.

Regional Natural Resources Management Boards

Eight regional NRM Boards provide strategic oversight for local and regional control programs for weeds. The role of NRM boards is to lead regional natural resources management through developing regional NRM plans, investing in weed management projects, advising government and connecting government to communities on relevant issues.

Regional NRM boards are supported by DEW staff, with a regional manager who is responsible to both the Chief Executive DEW and the NRM board.

This includes:

- reviewing regional NRM plans and weed management plans and prioritising buffel grass management in accordance with the Strategic Plan
- controlling buffel grass on road corridors and other lands for which they have responsibility for declared plants
- monitoring and evaluating success of buffel grass management
- promoting and supporting local and regional control programs in partnership with relevant stakeholders
- facilitating a coordinated approach to encourage stakeholders to include the strategic management of buffel grass in weed management planning
- initiating or sponsoring buffel grass funding submissions in line with state priorities
- in partnership with DEW, guiding local and regional mapping initiatives and contributing to state map production
- promoting awareness and best practice management through event coordination and product distribution.

Aboriginal land management authorities

Aboriginal land management authorities have been established across SA to assist traditional land owners to manage their land, including Aṉangu Pitjantjatjara Yankunytjatjara (APY) Land Management, Maralinga Tjarutja, and Yalata Aboriginal Community Council (Alinytjara Wilurara NRM Region), and the Aboriginal Lands Trust. The authorities work with Traditional Owners to ensure their cultural values are maintained and the ecological health of the land is retained.

This includes:

- improving knowledge of the identification, impacts and best practice control of buffel grass
- identifying priority sites for buffel grass control according to cultural values
- incorporating buffel grass management into Healthy Country plans in accordance with strategic management objectives (e.g. regional weed management plans)
- practicing good weed hygiene to minimise the spread of buffel grass
- implementing best practice management to reduce and / or remove buffel grass where possible and desirable
- monitoring and evaluating success of buffel grass management
- considering agreements across state borders to cooperatively manage buffel grass.

Private landholders

With the declaration of buffel grass under the NRM Act, landholders have a legislated requirement to control and manage it on their own lands in accordance with regional pest priorities.

This includes:

- improving knowledge of the identification, impacts and best practice control of buffel grass
- incorporating buffel grass management into property plans in accordance with strategic management objectives (e.g. regional weed management plans)
- practicing good weed hygiene to minimise the spread of buffel grass
- implementing best practice management
- monitoring and evaluating success of buffel grass management.

State government landholders

As the NRM Act binds the Crown, State government agencies with landholdings (e.g. DEW, DPTI, SA Water) have the same duty of care as private landholders in the control and management of buffel grass.

Department for Environment and Water (DEW)

DEW provides integrated environmental and natural resources services including management of the public land estate (parks, reserves and crown lands). DEW's role in managing the state's natural resources ranges from policy leadership to on-ground delivery with regional Natural Resources Management Boards, including issues relating to climate change, sustainable land management, and biodiversity conservation.

DEW has a supporting role for NRM boards to provide an integrated service delivery in each region on environment and NRM matters. Each region is led by a regional manager who is responsible to both the Chief Executive DEW and the regional NRM board.

This includes:

- including buffel grass in the development, implementation and/or review of management plans for the public land estate in accordance with the Strategic Plan
- monitoring and evaluating the success of buffel grass management
- facilitating the inclusion of strategic buffel grass management in pest management planning by stakeholders
- promoting and supporting local and regional control programs in partnership with relevant stakeholders
- supporting and/or developing buffel grass funding submissions in line with state priorities

- participating in local and regional mapping initiatives and contribute to state map production
- promoting awareness and best practice management through event coordination and product distribution.

Pastoral Program (PIRSA)

The Pastoral Board has a key role in preventing the introduction of buffel grass as a pasture species under the provisions of the Pastoral Land Management and Conservation Act, 1989. The introduction of plants not locally indigenous for the purpose of improving pasture values is not permitted without the written approval of the Board.

This includes:

- encouraging lease-holders to identify buffel grass and other weeds threatening the property
- facilitating the inclusion of strategic buffel grass management in property planning in accordance with this Strategic Plan and regional weed management plans
- encouraging lease-holders to implement good weed hygiene and other control measures to minimise the spread of buffel grass

SA Department of Planning, Transport, and Infrastructure (DPTI)

Buffel grass is commonly introduced into new areas along transport corridors from which it can spread into the surrounding landscape. Road managers therefore need to be aware of this risk, including the potential for a rapid build-up of buffel grass fuel in road reserves and the fire threat to infrastructure and the wider landscape. DPTI carries out vegetation control on roadside verges primarily for road safety (e.g. to provide sight distance) and for the maintenance of road infrastructure along state arterial and many outback roads. This maintenance can include management of weeds and other vegetation. While management of declared plants is the responsibility of the relevant NRM Board, improved outcomes and efficiency can be achieved by communication and coordination of roadside maintenance and weed control activities.

This includes:

- liaising with NRM Boards to facilitate effective and efficient buffel grass management on DPTI controlled land
- establishing local management protocols that contribute to strategic management objectives
- including weed hygiene and other prevention measures in work specifications and contractor inductions
- contributing to regional strategic control programs as part of road maintenance programs.

Local government

Within local government districts, councils are vested with care and control of most road reserves, with the exception of state arterial roads where DPTI typically assumes maintenance responsibility for a portion of the road reserve (see above). On state arterial roads the maintenance responsibility of councils is therefore reduced to the portion of road reserve between the road formation and the adjacent property boundary. Buffel grass is commonly introduced into new areas along transport corridors from which it can spread into the surrounding landscape. Local government authorities therefore need to be aware of this risk including the potential for a rapid build-up of buffel grass fuel in road reserves and other council-controlled land and the threat of fire to infrastructure and the wider landscape.

This includes:

- liaising with NRM Boards to facilitate effective and efficient buffel grass management on council-controlled land
- establishing local management protocols (e.g. weed hygiene) that contribute to strategic management objectives
- including weed hygiene and other prevention measures in work specifications
- contributing to strategic control programs as part of road maintenance programs
- improving community and industry awareness of impacts and identification, and promoting early detection.

Railway and service easement managers

Buffel grass is commonly introduced into new areas along transport corridors, rights of way and service easements (e.g. pipelines, transmission lines, Dog Fence) from which it can spread into the surrounding landscape. Managers therefore need to be aware of this risk including the potential for a rapid build-up of buffel grass fuel within the easement and the fire threat to infrastructure and the wider landscape.

This includes:

- establishing local management protocols (e.g. weed hygiene) that contribute to strategic management objectives
- managing buffel grass on rights of way and service easements
- monitoring and evaluating success of buffel grass management
- including weed hygiene and other prevention measures in work specifications
- contributing to strategic control programs and support NRM Boards undertaking control in rail corridor easements.

SA Department for Energy and Mining (DEM) and the Exploration, Mining, Petroleum and Geothermal Industries

As resource exploration and extraction are major activities across the state (including regions where buffel grass is prevalent) the exploration, mining, petroleum and geothermal industries have a duty of care to prevent the spread of weeds, including buffel grass. DEM issues licences, leases and work/activity approvals to the resource sector with conditions that ensure compliance with the control of weeds declared under the NRM Act.

This includes:

- establishing management policies to contribute to strategic management objectives
- including buffel grass management (e.g. weed hygiene to prevent introduction of buffel grass to new sites) in environmental approvals in accordance with the State Strategic Plan and regional weed management plans
- where appropriate, undertaking environmental approvals under the *Mining Act 1971* and the *Petroleum and Geothermal Energy Act 2000* including environmental outcomes or objectives that require exploration, mining, petroleum and geothermal companies to ensure no introduction of new weed species nor a sustained increase in abundance of existing weeds. Exploration, mining, petroleum and geothermal companies must then adopt management strategies to achieve those outcomes, including buffel grass management (e.g. weed hygiene to prevent introduction of buffel grass to new sites) in accordance with the State Strategic Plan and regional weed management plans
- improving community and industry awareness of impacts and identification, and promote early detection and rapid response.

Community Groups and Volunteers

Volunteer groups are making essential contributions to the detection and control of buffel grass infestations.

This includes:

- managing volunteer efforts that contribute to strategic management objectives.
- encouraging capacity building in volunteer networks.
- practicing good weed hygiene to minimise the spread of buffel grass.

Interstate government agencies

South Australia is the only state or territory to date that has declared buffel grass, and as such, no other jurisdiction has responsibility to control or remove buffel grass. However, the cooperation of other states and territories will help to reduce the ongoing invasion pressure of buffel grass into South Australia. A Buffel Free Great Victoria Desert Working Group has been formed to co-ordinate management in this desert which is shared between two states and the Northern Territory.

This includes:

- supporting South Australian declaration prohibiting the movement of contaminated goods, machinery livestock and materials into the state
- cooperating with South Australian agencies in determining the distribution of buffel grass across common state borders
- avoiding the release of new cultivars where there is a high risk of natural or inadvertent human spread into and establishment within South Australia.

Research institutions

Universities are the key research bodies that can fill knowledge gaps in the control of buffel grass. South Australia's three universities (Adelaide, South Australia and Flinders) should be encouraged and empowered to source funding and resources for researchers in support of this task. Contribution from interstate and overseas (e.g. USA) universities is also encouraged.

This includes:

- identifying research gaps and seeking innovative solutions for the management of buffel grass
- seeking new and on-going funding and support for research requirements.

Case study:

Working across borders

The Great Victoria Desert (GVD) is the largest desert in Australia and contains significant biodiversity and cultural values. One of the key threats to the GVD includes the encroachment of buffel grass which is transforming arid landscapes and fire behaviour across outback Australia.

Buffel grass has limited distribution across the GVD but if left unmanaged, it is predicted to spread across vast areas of this relatively intact bioregion. Buffel grass threatens habitat and places further pressure on threatened and vulnerable species that live in the GVD including:

Vertebrates listed under the Environment Protection Biodiversity Conservation Act (EPBC Act)

- Sandhill dunnart, *Sminthopsis psammophila* (endangered)
- Southern marsupial mole, *Notoryctes typhlops* (endangered)
- Malleefowl or nganamara, *Leipoa ocellata* (vulnerable)
- Black footed rock wallaby or warru, *Petrogale lateralis* (vulnerable)
- Bilby, *Macrotis lagotis* (vulnerable)
- Western quoll or chuditch, *Dasyurus geoffroii* (vulnerable)
- Crest-tailed mulgara, *Dasycercus cristicauda* (vulnerable)
- Princess parrot, *Polytelis alexandrae* (vulnerable)
- Great desert skink, *Liopholis kintorei* (vulnerable)
- Greater stick nest rat, *Leporillus conditor* (vulnerable).

Plant species listed under the EPBC Act:

- Victoria desert smoke bush, *Conospermum toddii* (endangered)
- Ponton creek mallee, *Eucalyptus articulata* (vulnerable)
- Ooldea guinea-flower, *Hibbertia crispula* (vulnerable)
- Yellow Swainson-pea, *Swainsona pyrophila* (vulnerable)
- Bead samphire, *Tecticornia flabelliformis* (vulnerable).

The buffel grass free GVD (BFGVD) project was initiated in 2015, with the goal to eradicate buffel grass from the GVD. It is now a part of the 10 Deserts Project. To work towards achieving a buffel free GVD the project aims to:

- identify and map existing buffel grass infestations within the GVD
- improve the capacity and capability of land managers to manage buffel grass
- reduce buffel grass infestations through active management
- prevent new infestations of buffel grass from establishing in the GVD
- implement a more coordinated approach across the GVD
- test buffel grass control strategies for broader application in other desert regions

Rangers from the APY Lands spraying buffel grass

Indigenous land management organisations are leading collaborative action against buffel grass across the GVD, supported by a number of land and resource management organisations – they make up the *BFGVD Working Group*. The BFGVD working group includes partners from across the GVD including:

- Anangu Pitjantjatjara Yankunytjatjara Lands Management (SA)
- Arid Lands Environment Centre (NT)
- Charles Darwin University (NT)
- Desert Support Services (WA)
- Great Victoria Desert Biodiversity Trust (WA)
- Maralinga Tjarutja Land Management (SA)
- Natural Resources Alinytjara Wilurara (SA)
- Rangelands NRM (WA)
- Ngaanyatjarra Land Management (WA)
- Primary Industries and Regions South Australia (PIRSA)
- Spinifex Land Management (WA)

The working group meets quarterly to share updates, data and organise on-country workshops to build capacity and implement the management plan across the GVD. The first Southern Desert Ranger Forum (SDRF) in Ilkurlka Spinifex Country, Western Australia in 2017 was initiated through the BFGVD working group. The SDRF has become an annual event for Indigenous rangers to learn skills, build capacity and share knowledge across and surrounding the GVD.

The working group has developed an *Integrated Buffel Grass Management Plan for the Great Victoria Desert.* The plan identifies key priority management actions across the six sub-regions of GVD with key introduction pathways into the GVD including the Trans-Continental rail line and key roads, tracks and communities. It also provides the basis for standardised data collection and analysis across the bioregion.

The plan identifies opportunities for sustained gains in the battle against buffel grass through developing culturally appropriate communication products to highlight the risks of its spread and how important vehicle hygiene is in protecting culturally and ecologically important areas.

Building a long-term sustainable model is critical to this project's success. The 10 Deserts Project provides a solid base to support collaboration across the GVD in the short term. In the medium to long-term, leadership like that shown by the South Australian Government's listing of buffel grass is needed. This leadership combined with cross-border commitments of state governments to support key bioregions like the GVD to manage *mamu tjanpi* (devil grass) will ensure future generations experience the wonder of these desert landscapes and not be subjected to vast, flammable monocultures of buffel grass.

3.5 Monitoring and evaluation

Monitoring and evaluation are important to the continued development of the State Strategic Plan to improve the effectiveness of management actions. This strategic plan is subject to a five year review.

The national NRM Monitoring, Evaluation, Reporting and Improvement (MERI) Framework has been adopted by the South Australian government for monitoring natural resource management targets. Applied to this strategic plan, the MERI Framework should measure the effectiveness of specific management actions on achieving measurable outcomes.

The implementation of the plan will be monitored by the State Buffel Grass Taskforce, via biennial reports. These will comprise an assessment of progress against the goals of the plan, as set out in section 2, identifying which have been achieved, are underway or have not been achieved. For the latter category, the reasons for not achieving them should be identified and recommendations made for facilitating attainment of these goals.

Herbicide trial site (foreground) in buffel grass monoculture, Umuwa, APY Lands.

Effective herbicide trial results, Umuwa, APY Lands.

4 Technical Background

4.1 Description

Buffel grass is an erect, deep-rooted, tussock forming, C4, summer-growing perennial grass. Seed heads are dense, white to purple in colour, growing in a spike-like raceme up to 15 cm long and are covered in clusters of bristles giving them a fluffy appearance; the flowering heads appear from November to May or sporadically following rain (Smith 2002). The bristly burrs are borne on a zigzag central axis (figure 2).

Buffel grass is native to Africa, India and the Middle East (Whyte *et al.* 1959; Humphreys 1967).

Buffel grass (*Cenchrus ciliaris*) seed heads.

4.2 Taxonomy

The more common of the two species declared as buffel grass, *Cenchrus ciliaris* L., has highly variable morphological and physiological characteristics, reflecting its wide native range. This intraspecific variation has arisen both naturally and from the development of new strains to improve productivity of pastoral land. Cultivars have been developed commercially with increased growth rates, disease resistance and tolerance to a range of environmental conditions. Marshall *et al*. (2012) suggest that knowledge about the suitability of various strains in different environments may be critical for effective control of infestations.

Caution should be taken to ensure that records of *Cenchrus* species are credible, as a number of grasses in this genus can be difficult to distinguish from one another, and from grasses in the closely related genus *Pennisetum*.

Three other *Cenchrus* species that are considered invasive weeds of natural rangelands in some parts of Australia but are much less common in this state than *C. ciliaris*, are also considered in this plan:

- *C. pennisetiformis* Steud. is also included under buffel grass in the Declaration. It is also called Cloncurry grass or slender buffel grass.
- Birdwood grass (*C. setiger* Vahl)
- Mossman River grass (*C. echinatus* L.)

C. pennisetiformis, native to northern Africa, Arabia and India, is difficult to distinguish morphologically from *C. ciliaris*, and until recently they were considered to be the same species. It is also used for permanent pasture and has similar ecological requirements and invasive properties.

Birdwood grass *C. setiger*, native to Africa and India, is a perennial grass that is similar to smaller types of *C. ciliaris*. It has been planted as a fodder plant in pastoral areas in other states and is adapted to a wider range of soils and is more drought tolerant than *C. ciliaris*.

Mossman River grass *C. echinatus*, native to North and South America, is an annual grass forming loose tussocks and characterised by large spiny burrs. It has not been deliberately cultivated in Australia and is regarded as a pest of pastures and some crops.

4.3 Reproduction

Buffel grass plants are bisexual and commonly reproduce by seed (produced with or without fertilisation) or vegetatively through rhizome or stolon production (Franks 2002). After ripening and shedding from the plant, seeds remain viable for 12 months or longer. Field experiments conducted near Alice Springs (Winkworth 1971) found that a small portion of the seeds can remain viable for up to 4 years in the soil, however only 10% were viable after 2 years. Other studies (e.g. Silcock and Smith 1990) suggest that seed can survive 2-4 years in the soil.

Generally at least 25 mm of rainfall is required for seed germination (Cavaye 1988), with germination beginning immediately after rain and peaking in 3–6 days (Tinoco-Ojanguren 2016).

Wildfires may encourage germination as the ashes are reported to make good seedbeds (Paul and Lee 1978). Franks (2002) suggests that buffel grass seeds are triggered to germinate by even minor forms of soil disturbance, including breaking of the soil surface by stock movement.

Seedlings can reach reproductive size and set seed in as little as 3 to 6 weeks with sufficient moisture and re-shooting mature plants can flower within 10 days after a rainfall event (Dixon *et al* 2002; Puckey and Albrecht 2004).

4.4 Preferred habitat

Buffel grass currently predominates in areas where summer rainfall varies from 150-550 mm, winter rainfall is less than 400 mm, mean minimum winter temperatures rarely fall below 5°C, and soil texture is loamy (Cox *et al.* 1988). It favours creeks, alluvial plains, calcareous areas and rocky ranges (Albrecht and Pitts 1997), however, it has been successful in a broad range of soil types and landscapes. Buffel grass also readily establishes in road and track verges, parking bays, towns and other disturbed areas.

4.5 Dispersal and Persistence

Buffel grass spreads through dispersal of its fluffy burrs by water, wind, accidental transportation (e.g. in or on vehicles, animals, soils, etc.) or inadvertently transported (e.g. in hay) or, intentionally introduced by landholders seeking to establish an improved pasture (Puckey and Albrecht 2004). Seeds rarely survive ingestion and it is unlikely that herbivores are responsible for significant spread of buffel grass in this manner (Gardner *et al.* as cited in Griffin 1993).

Seeds are commonly introduced into new areas along roads and tracks. Spread along roads is assisted by vehicle draughts and movement of soil by graders and other machinery and vehicles. From the road or track verge buffel grass then spreads into the surrounding vegetation by wind or water, with drainage lines acting as conduits for more distant dispersal (Puckey and Albrecht 2004).

Buffel grass may initially be slow to establish, but under favourable seasonal conditions it may spread readily and aggressively invade arid riparian areas. Established buffel grass tussocks can remain dormant for long periods and plants can live for at least 20 years (Latz 1997). Leaves die off during dry or cold periods and new growth quickly emerges from the tussock with warm, moist conditions.

Buffel grass has a rapid growth rate, fast maturation, prolonged flowering/fruiting periods, prolific seed production, high seed dispersal ability, relatively long seed dormancy, and is tolerant to drought, fire and grazing (Franks 2002; Franks *et al.* 2000). In the arid zone, it has spread extensively during infrequent episodes when summer rainfall was well above average for several years.

Buffel grass is competitive as an established plant and less competitive as a seedling. To limit its dominance it is therefore important to maintain competition from existing vegetation, however, this is unlikely to prevent spread altogether (McIvor 2003).

4.6 Impacts and uses

Buffel grass forms dense monocultures, changes fire regimes, threatens refugia and displaces native and endemic plants (McIvor 2003; Humphries *et al.* 1991; Griffen 1993; Low 1997). It has been identified as a 'transformer' species (Grice 2006); Richardson et al. (2000) have defined these as 'a sub-set of invasive plants which change the character, condition, form or nature of ecosystems over a substantial area relative to the extent of that ecosystem'. Bastin *et al.* (2008) identified it as a 'transformer weed' of the Australian rangelands. In NSW, the Invasion of native plant communities by exotic perennial grasses" is listed as a Key Threatening Process (KTP) under the *Threatened Species Conservation Act 1995*. Buffel grass is one of these grasses listed under this KTP.

Buffel grass aggressively and rapidly colonises preferred habitats where it forms dense monocultures, displacing native vegetation. In arid Australia, buffel grass often displays strongest growth along creek lines and embankments (Centre for Arid Zone Research 2001). Watercourses and other mesic areas are functionally critical in a landscape where water is limiting to growth. Mesic areas are also nutrient sinks and tend to support higher flora and fauna productivity, including endemic or rare species (Humphries *et al.* 1993).

Numerous studies have shown that the cover of buffel grass is negatively associated with species richness (e.g. Clarke *et al.* 2005). Where buffel grass density is high it is predicted that reductions in species richness will become more pronounced over time, because the seed banks of native forbs and grasses will gradually be depleted (Clarke *et al.* 2005).

Buffel grass threatens plant and animal communities that are not adapted to fire, by increasing the intensity and frequency of natural fire regimes (Adair and Groves 1998; Schlesinger *et al* 2013). Dry foliage can form a relatively continuous, flammable ground layer that can carry extensive and intense fires. Buffel grass produces approximately 2-3 times the combustible material of displaced native grasses, resulting in hotter, more intense fires (Humphries 1993) and is able to rapidly regenerate after fire and suppress regeneration of native species. An aspect of the ability of buffel grass to transform the fire regime at a landscape scale, particularly in dry environments, is its ability to infest creek-lines which would otherwise act as natural barriers to the spread of fire. In such environments, where creek-lines did not naturally support the growth of dense, fire-fuelling grasses, buffel grass can act as a "wick" for the transmission of a fire across the landscape.

Case study:

Impact of Buffel Grass on Aboriginal Culture

As buffel grass continues to invade and change ecosystems across large areas, Aboriginal people are experiencing the effects of this landscape transformation as bushfoods decline, human safety is threatened, and Aboriginal culture is impacted (Bowman 2017).

Two short films and one episode of ABC's *Landline* have investigated the effects of buffel grass on Aboriginal culture in remote Australia. ABC *Landline's* episode "Mixed Blessing", the short film "Storm on the Horizon" by Ninti Media and PIRSA, and the short film "Desert Rangers War on Buffel Grass" by the Ten Deserts Initiative all interviewed Aboriginal elders, rangers and ecologists across the APY Lands (SA) and Spinifex Country (WA) in order to find out how the rapid invasion of buffel grass is affecting the culture of Aṉangu people.

Ili, **one of the most important bushfoods**.

Many Aṉangu in the films describe how buffel grass has dramatically changed the understorey vegetation: previously the plains country supported an abundance of bush foods, wildflowers and native grasses but now buffel grass has taken over and few of these species remain. Aṉangu remember being healthy eating many bush foods but now their health has deteriorated. Kampurarpa (*Solanum centrale*), wakati (*Portulaca oleracea*) and wangunu (*Eragrostis* spp.) are staple bush foods which are specifically mentioned in the films as having been lost from large areas due to buffel grass invasion. Buffel grass also has the ability to grow right under trees and shrubs, which more easily carries fire and burns tree and shrub bush food and resource species such as ili (*Ficus brachypoda*) and ilykuwara (*Acacia kempeana*) and apara (*Eucalyptus camaldulensis*). Many bush medicine plants are also threatened directly by buffel grass and the hot buffel-grass fires.

Aṉangu women in the films explain how they are scared to hunt for maku (witchetty grubs) and tjala (honey ants) because buffel grass is so dense that they cannot see snakes when out hunting. Aṉangu men also say the thick buffel grass covers up tracks of key bush tucker species like ngintaka (perentie lizard) making hunting more difficult, and they have observed bush tucker species used for meat are in decline.

As buffel grass fuels hotter, more intense and more frequent fires, the whole fire regime of the ecosystem is changing. This impacts upon the ability of Aṉangu to use fire for many of their cultural practices. Human safety in remote Aboriginal communities is definitely at risk when surrounded by dry, large and continuous tussocks of buffel grass.

Overall the invasive buffel grass has been described by the Spinifex Rangers as destroying the Aṉangu way of life, because "you need the country, you need the animals to hunt and the plants to keep, and once that's all gone, basically you've got nothing left."

Thick buffel grass growing under the important bush food wattleseed *Acacia victoriae*

Pitjantjatjara names have been used for plants and animals. Films describing the impact on buffel grass on Aboriginal culture can be found online at:

"Storm on the Horizon" pir.sa.gov.au/buffel-grass

"Mixed Blessing"
abc.net.au/news/2015-02-02/mixed-blessing/6063502

"Desert Rangers War on Buffel Grass"
https://youtu.be/6kyTaRSW87U

Buffel grass threatens stands of long-unburnt vegetation, and the fauna that rely on these, for example mulga woodlands, hummock and spinifex grasslands. Research undertaken in central Queensland found counts of the native delicate mouse (*Pseudomys delicatulus*) declined as the cover of buffel grass increased (Ludwig *et al.* 2000).

Rare and endangered fauna species in northern SA threatened by buffel grass include: black-footed rock wallaby; great desert skink; spinifex bird; mallee fowl; and a suite of ground / low shrub / grassland foraging birds such as chestnut quail thrush, dusk grass wren, and striated grass wren (Paltridge *et al.* 2009). The Rare and Threatened Flora Management Plan for the APY Lands (Paltridge *et al.* 2009) identifies 12 plant species under threat from buffel grass. Appendix 4 provides a listing of indigenous flora and fauna species of conservation significance that are currently considered to be threatened by buffel grass in arid and semi-arid South Australia.

Buffel grass has been the subject of agricultural extension activity in northern Australia since the 1920s (Humphrys 1967); in the 1950s it became the prominent sown pasture grass for the more arid zones of northern Australia and was well researched for its potential to improve pastures across Queensland, Western Australia and the Northern Territory (Hall 2000). Most plantings have taken place since the late 1950s (Paull and Lee 1978).

Buffel grass is regarded as a resource by many northern Australian cattle producers because of its palatability, responsiveness to limited rainfall, ability to colonise and its tolerance to drought and heavy grazing (Fairfax and Fensham 2000). It responds to out of season rain when native species remain dormant (Hall 2000), however it can displace a large range of short-lived native grasses and forbs important in fattening cattle (Puckey and Albrecht 2004). This is of particular concern in far northern SA where these types of vegetation communities predominate (Greenfield 2007). It provides less protein and metabolisable energy than native grasses such as barley Mitchell grass (*Astrebla pectinata*), spear grasses (*Austrostipa* spp.), silky blue-grass (*Dichanthium sericeum*) and black-head grass (*Enneapogon nigricans*), insufficient to maintain adult dry stock in the absence of other feed (Natural Resources SA Arid Lands 2017).

Buffel grass invasion is facilitated by burning, producing positive feed-back between buffel grass and the fire. The consequence of this positive feedback loop is an increased rate of degradation of the landscape as buffel grass increases in density and out-competes non-fire-dependent native species and further dominates the ground layer (Butler and Fairfax 2003; Miller et al. 2010).

Buffel grass has a high demand for available soil nitrogen and phosphorus. As it assumes dominance, soil nitrogen is depleted and growth begins to decline in what has been described as a 'run-down' effect, with an associated decline in cattle live-weight gain (Puckey and Albrecht 2004). Buffel grass contains oxalates and can cause acute oxalate poisoning in ruminants, most often in young and hungry sheep (Thomas 2004). Under favourable conditions buffel grass can form monocultures or dense stands, displacing native plants including valuable forage species. Lack of diversity in pastures can limit the nutritive value available to stock during particular seasonal conditions (e.g. dry periods) or pasture "run-down".

Buffel grass has also been used for soil stabilisation and erosion control (Albrecht and Pitts 1997).

Major threats to country in South Australia include invasions of existing or new weeds, in particular buffel grass, which is considered one of the greatest risks to biodiversity and culture in the Alinytjara Wilurara Natural Resources Management Region (Alinytjara Wilurara Natural Resources Management Board, 2011). Biodiversity assets at risk within the region include culturally important or unique flora, fauna (e.g. the critically endangered warru or black-footed rock wallaby) and native habitats. Cultural practices at risk due to the impacts of buffel grass include collection of bush foods and medicine, hunting and tracking techniques due to a loss of species diversity and inter-tussock space and practices associated with cultural burning and 'special places' that are being overrun by buffel grass and impacted by wildfires.

Case study:

Addressing the threat of buffel grass to warru in the APY Lands

As buffel grass continues to invade and change The black-footed rock wallaby *Petrogale lateralis* (MacDonnell Ranges race), known as warru in Pitjantjatjara, has drastically declined in abundance and distribution since the arrival of Europeans in Australia. This species is now listed as critically endangered in South Australia with two remaining wild populations, one reintroduced population and one semi-captive population in the rocky hills of the Aṉangu Pitjantjatjara Yankunytjatjara (APY) Lands.

Buffel grass is threatening warru primarily by changing the fire regime. Buffel grass promotes hotter and more frequent fires due to its higher fuel load and ability to regenerate more quickly than native grasses. Currently, buffel grass has expanded throughout the northern part of the APY Lands, forming dense infestations particularly in the outwash areas adjacent to hills and increasingly up on the hills and right under overstorey vegetation. Increased fire intensity and frequency can destroy trees and smaller plants, many of which are important food for warru, such as fire-sensitive desert fig (*Ficus brachypoda*) and spearwood (*Pandorea pandorana*). More frequent fires could also reduce the vegetation cover which affords warru protection from predation by foxes and cats. Overall, buffel grass is changing the ecosystem where warru live and without management buffel grass could contribute to a further decline in warru populations.

Because the infestations around warru habitat range from dense to isolated patches, different management techniques have been employed by the Warru Recovery Team and Indigenous Rangers from APY Land Management. Given the remote area, hot arid climate, fluid workforce and high turnover of staff, there are challenges to reducing the threat of buffel grass around warru populations. For example, herbicides may not be as effective with either too little or too much rain and application on hot days; follow up is difficult with high turnover of staff; and carting water and PPE to remote sites is time-consuming and reduces the amount of area that can be covered. The four different warru populations have received different management strategies, which highlight some of these challenges:

In the far west of APY at Kalka community, buffel grass has already invaded the plains at the base of hills and is now climbing up hillsides and creeklines. Buffel grass control is focussed within creeklines of ecological and cultural importance. In Maku Valley rangers opted for a more delicate method of buffel grass control to avoid herbicide runoff impacting aquatic organisms such as rare frogs. Hand grubbing of buffel grass was completed in a 25

Looking after warru on the APY Lands with ranger Jacob MacKenzie

metre radius around the Maku Valley spring in early 2016, but after winter rains ruby dock, another resident weed in the APY Lands, covered the area. Following summer rains, buffel grass germinated again to worse than pre-control levels. However, with continual hand removal in 2017/2018, the Ranger team are maintaining a low density of buffel grass around the key ecological and cultural site in Maku Valley. In previous years, 360g/L glyphosate was sprayed in the same area but this was not fully effective.

At ‘Pintji’, the fenced exclosure containing captive-bred warru prior to their release, buffel grass is invading along tracksides and into the exclosure due to seed transport by wind, vehicles and human foot traffic. Tracksides and isolated patches were targeted in 2016 by spraying with a mixture of glyphosate/flupropanate to kill mature tussocks, prevent seeding and stop new recruits from emerging in following seasons. However, follow up monitoring detected new plants and several old plants which had re-sprouted. Overall the 2016 spraying was not considered successful, which could be due to poor water quality used in the

spraying mix. In winter 2017, dry granular flupropanate was shaken over specific buffel grass tussocks at a rate considered equal to 25 kg/ha. However, at this rate of hand application the granular flupropanate was not considered successful either, as after early summer rains finally activated the granular product, up to 20% of each buffel grass tussock maintained healthy growth. In winter 2018, a spray mix of glyphosate, flupropanate and the new addition of pine oil was used along roadsides and for isolated patches, with results yet to be confirmed.

Warru have recently been translocated to 'Wamitjara', a remote hill or inselberg away from the main area of buffel grass infestation. However, buffel grass has been found in small patches along tracksides, at camps and on the hillside. The remote location and isolated infestation makes this area suitable for dry granular flupropanate application. In winter 2017 the granular application was undertaken opportunistically, however, similar to at the Pintji, the granular flupropante did not prove to be effective. Follow up control has occurred in June/July 2018 with a liquid spray mixture of glyphosate, flupropanate and pine oil applied to plants within approximately 60m either side of the loop track that encircles Wamitjara. This is the first time that pine oil has been trialled to control buffel grass in the APY Lands. Effectiveness of this treatment approach should be evident after summer rainfall. If effective, backpack spray units with this herbicide mix will be used to control buffel grass on the hill at Wamitjara and other project sites.

The main wild population of warru occurs at 'New Well' which is a large hill close to Ernabella. Buffel grass now occupies approximately one third of the plains surrounding the mountain, which poses an increased fire risk and is a source for buffel grass to invade up the hillside. Due to the size of this infestation, vehicle-based control is difficult. Application of the granular flupropanate at 22.5 kg/ha was trialled by helicopter in July 2017 to cover 90 hectares to provide residual control of buffel over large areas. This method provided partially effective as only a portion of each mature tussock was killed.

4.7 History of spread

Buffel grass is believed to have been accidentally introduced into the north-west coast of Western Australia in the 1870s in Afghan camel harnesses (Humphreys 1967). After the First World War, the WA Department of Agriculture was active in distributing *Cenchrus* varieties sent from Afghanistan. These were the source of the first buffel grass seeds being planted in Queensland at Cloncurry in 1926 (Humphreys 1967). Trials of buffel grass from Pretoria were recorded in the early 1920s in NSW and a buffel grass specimen was identified in Alice Springs in 1930 (Humphreys 1967). Since the late 1950s, buffel grass has been a major pasture grass sown in northern Australia (Loch 1999). Over 580 accessions of buffel grass have been brought into Australia from 35 countries by various agencies (Hall 2000) with new varieties continuing to be introduced (Friedel *et al.* 2006). Considerable genetic diversity was detected in field samples of *Cenchrus ciliaris*, and evidence of crossing between varieties shows the potential for recombinant forms to arise (Waycott 2006).

Buffel grass has been accidentally and intentionally introduced around northern South Australia. Small scale buffel grass trials have been carried out on many pastoral properties in South Australia since the 1950s (Greenfield 2007). Wind, water, animals and machinery dispersal vectors have spread it into other areas.

Declaration under the *Natural Resources Management Act 2004* prohibits further entry of buffel grass to South Australia, its sale, or transport on public roads either by itself or as a contaminant of produce. This is intended to minimise further movement by human activities.

4.8 Current distribution

Buffel grass is naturalised in Western Australia, the Northern Territory, Queensland, New South Wales and South Australia.

Current distribution data (Figure 1) consists of data collected by DPTI, regional NRM officers, the biological database of South Australia and numerous roadside surveys conducted since 2005. In South Australia, buffel grass is widely distributed across the northern regions with scattered populations varying in size and density (Figure 1). Extensive infestations occur in the state's far north-west, in the northern part of the AW NRM Region (APY Lands). Infestations are present in the Maralinga Tjarutja (MT) Lands and southern Alinytjara Wilurara (AW) NRM Region. Infestations also occur in and around the communities of Oak Valley, Maralinga and Yalata, along the east-west rail corridor from east of Barton to west of Ooldea and Cook, along the Eyre Highway and Lake Dey-Dey road, in the Tallaringa and Mamungari Conservation Parks and Nullabor Regional Reserve and National Park. These infestations are of particular concern because they threaten the cultural and environmental assets of the Great Victoria Desert.

In the SAAL NRM Region buffel grass is widely distributed as scattered populations with most located in the northwest (Marla – Oodnadatta District). North of Marla, along the Stuart Highway verge and adjoining land, buffel grass densities are high; south of Marla the density and extent declines, particularly away from the highway. Infestations of particular concern in the SAAL NRM Region include those in Witchera National Park (the gateway to the Simpson Desert), Innamincka Regional Reserve (threatening the Coongie Lakes complex-a nationally recognised Ramsar site of floodplains and dunefields) and small isolated populations along various roads and tracks acting as introduction pathways into uninfested sites of cultural and environmental significance.

In the Northern and Yorke NRM region there are small roadside populations along the Stirling North - Hawker road and an extensive infestation along the Port Augusta - Port Wakefield Road between Port Augusta and Port Pirie. There are relatively few infestations in the southern parts of the state. In early 2012 several small infestations were found within the SA Murray Darling Basin (SAMDB) NRM region with a number of small infestations found between 2015 and 2017 due to increased awareness and surveillance efforts. 52 infestations are now being managed in the SAMDB NRM region; prior to 2012, buffel grass had been recorded from only one location within the region (2004).

There is a growing number of as yet small, isolated infestations in the EP NRM region, typically associated with roadsides and townships.

In 2015 and 2016, five buffel grass infestations were found in the Adelaide and Mount Lofty Ranges (AMLR) NRM region. These infestations occurred in Port Adelaide, Bowden, along the Port Wakefield road and Northern Expressway. Two records of buffel grass were found in the South East NRM region in the road and railway corridor along the Dukes highway near Keith in 2015.

With the exception of the far north-west, known non-roadside occurrences of buffel grass are widely scattered and sparse. These infestations are mostly small; however its distribution along some watercourses is likely to be more extensive, for example in the North Flinders District of the SAAL NRM Region. Isolated infestations occur along the Oodnadatta Track, Coober Pedy - William Creek Road, Borefield Track, Marree – Hawker Road, Birdsville and Strzelecki Tracks, and in townships including Marla, Oodnadatta, Cooper Pedy, Copley, Glendambo, Roxby Downs and Port Augusta.

However, although many of the known infestations occur along roadsides, this is likely to reflect a significant bias resulting from presence and absence data being largely collected through roadside surveys. Significant infestations may well exist on pastoral properties and in drainage lines outside the scope of roadside surveys and therefore the true full extent of buffel grass distribution throughout South Australia is likely much more extensive than is currently known.

4.9 Potential distribution

Using BIOCLIM climatic modelling it has been predicted that 25% of Australia is potentially highly suitable, and 43% is suitable for buffel grass spread, with the arid to semi-arid areas of the continent being potentially the most favoured for this species (Lawson *et al.* 2004). The MaxEnt model indicated buffel grass intolerance to cold and wet stress, and regions where there are insufficient days above the minimum threshold temperature necessary for the species to complete a generation.

More recent climatic modelling for South Australia using MaxEnt[3] (Hobbs *et al* 2015) predicted that no part of the state's land area is entirely unsuitable for establishment of buffel grass (See Table 1 and Figure 3). The model also showed that the degree of suitability for establishment is variable across the state: 4% is "moderately suitable", a further 9% is "suitable", and a further 42% is "highly suitable". A relatively large proportion of the state (45% or 45,000 ha, confined mainly to the SA Arid Lands and Alinytjara Wilurara regions) was predicted as "very highly suitable".

Current breeding programs interstate may result in the use of buffel grass as pasture being extended to heavier soils and cooler regions. As a consequence, new forms of buffel grass may have the potential to invade a wider range of habitats.

Climate change modelling undertaken by Macquarie University in conjunction with the NSW Office of Environment and Heritage suggests that suitable climatic habitat for this weed will shift from northern and central Australia towards south-eastern Australia, including large areas in South Australia and New South Wales (Wilson *et al.* 2011).

[3] MaxEnt is a species distribution model that generates climate estimates based on meteorological data and topographical information. User input of the distribution of taxa is used to create climatic profiles, which can subsequently allow predictions of further distributions of these taxa (Busby 1991). BIOCLIM requires precipitation and temperature information, but does not take substrate into account.

Climatic suitability category	NRM Region Percentage of land area							
	SAAL	AW	SAMDB	NY	EP	KI	AMLR	SE
Not suitable	0	0	0	0	0	0	0	0
Moderately suitable	9	0.1	27.1	35.2	0.8	56.8	60.7	79.6
Suitable	47.6	38.2	37.2	35.2	6.7	43.2	21.6	20.4
Highly suitable	52	26.5	55.8	22.3	45	1	9.1	0
Very highly suitable	39	73.4	8.4	24.9	47.6	0	8.6	0

Table 1: Climatic suitability for establishment of buffel grass in South Australia: Percentage of land area within each NRM Region in each suitability category. The analysis using BIOCLIM (Marshall and Hobbs, 2010) was based on existing distribution records sourced from Biological Survey SA, Australian Virtual Herbarium, NRM regions, and local government groups, as well as roadside survey data (Shepherd and Marshall, 2010).

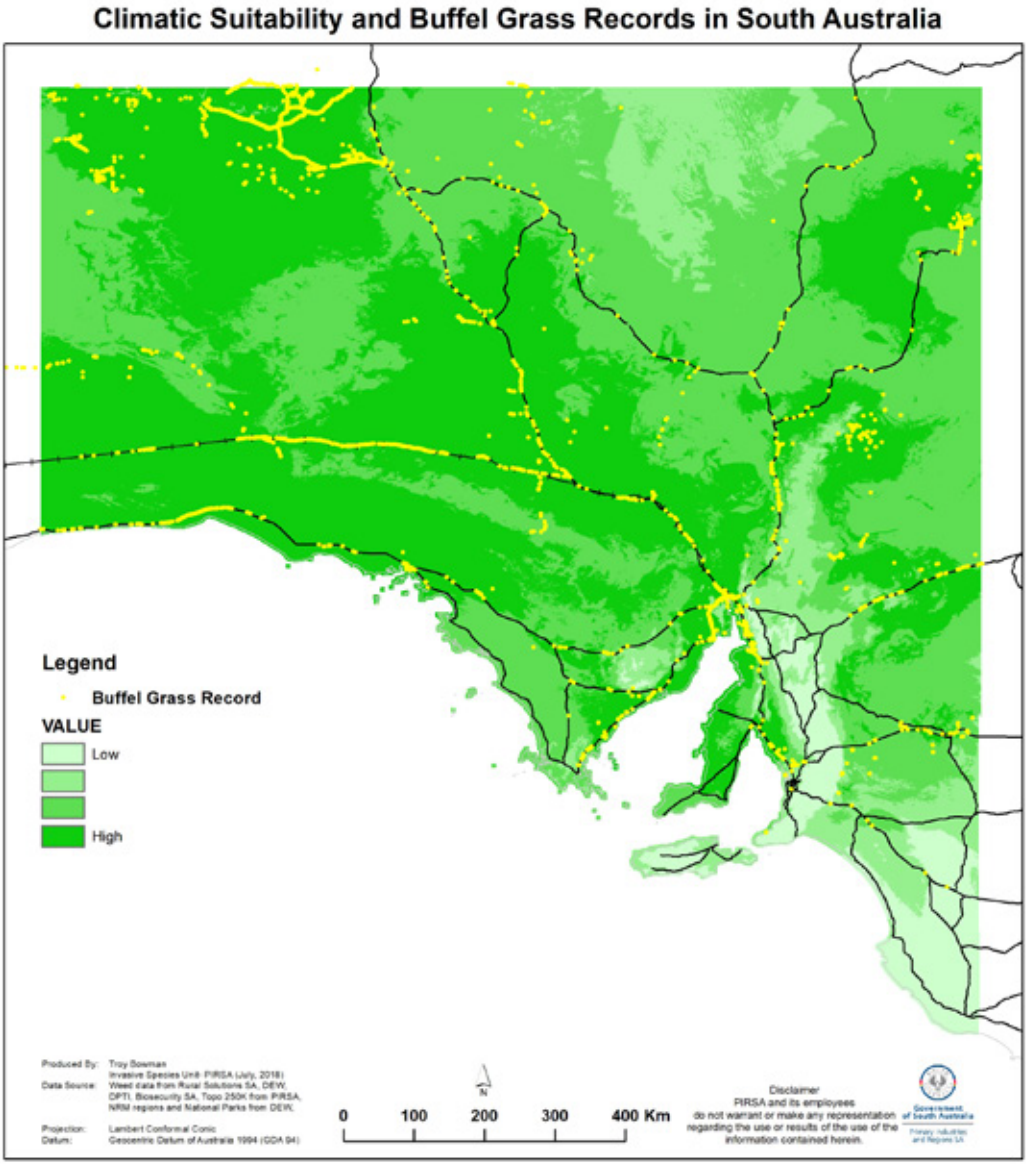

Figure 2. Climatic suitability and distribution records in South in South Australia.
Climatic suitability is based on MaxEnt analysis. Current records are based on a range of sources including Australasian Virtual Herbarium, Rural Solutions SA, Department for Environment and Water, Department of Planning, Transport and Infrastructure and the Department of Primary Industries and Regions SA.

4.10 Risk Assessment

An updated state-level weed risk assessment was carried out in 2018 using the SA Weed Risk Management System (Virtue 2008) for the following land-uses:

Rangeland grazing:

Land-use is grazing on leases under the Pastoral Management Act, and also Aboriginal lands where these are grazed. It occurs in the arid and semi-arid parts of the state mainly in the AW and SAAL NRM Regions. Weed management is assumed to be sporadic and minimal in this land-use.

Native vegetation (whole state):

This land-use includes both public and private lands supporting native vegetation in all regions of the state. It includes all forms of land tenure including public and private protected areas and other land. It is assumed there is no routine weed management in this land-use.

The results of the assessment are given in Table 2 below.

Table 2: State-level risk assessment of buffel grass for two land-uses in South Australia using the SA Weed Risk Management System.

Land use	Weed risk (score)	Feasibility of containment (score)	State Level Management Response
Rangeland grazing	Very high (303)	Negligible (184)	Manage weed
Native vegetation	Very high (371)	Low (58)	Protect sites and manage weed

The assessed weed risk is very high for both land-uses due particularly to its invasiveness, especially its easy dispersal, high potential distribution and the impact on desired vegetation.

The lower assessment of its feasibility of containment for both land-uses is due to increased knowledge of biology of the plant, increases in buffel grass distribution, and our knowledge of this since 2013.

It is important to note that this is a state level risk assessment and regional risk assessments should be carried out to support development of regional management plans.

Feasibility of containment is lower for the rangeland grazing land use than for native vegetation across the whole state, principally due to the greater abundance and wider distribution of buffel grass in the arid and semi-arid regions. At a sub-regional level, feasibility of containment would be lowest in the APY Lands in the far north-west of the state due their remoteness and the extent of land infested by the weed there.

In the rangeland grazing land-use, the aim of a “Manage weed” response is to reduce the overall economic, environmental and social impacts of the weed through targeted management.

In the native vegetation land-use, the aim of a “Protect sites” response is to prevent the spread of the weed to key sites and assets of high economic, environmental and social value.

Regional

In 2014, weed risk assessments for buffel grass using the SA Weed Risk Management System were undertaken for NRM Regions where the risk of introduction and establishment is considered to be the greatest in South Australia. The following regional-level management responses have been determined. It should be noted that knowledge of buffel grass distribution and ecology has improved considerably since 2014, and that consideration should be given to updating these assessments in line with the state-level risk assessment.

NRM Board	Management response as determined by weed risk assessments
Alinytjara Wilurara	Protect sites (APY Lands) Destroy infestations (MT Lands)
SA Arid Lands	Manage weed (Marla-Oodnadatta) Protect sites (all other Districts)
Eyre Peninsula	Destroy infestations
Northern and Yorke	Contain spread in native vegetation Monitor in non-arable grazing
SA Murray Darling Basin	Destroy infestations
Adelaide and Mt Lofty Ranges	Destroy infestations
South East	Destroy infestations
Kangaroo Island	Destroy infestations

Case study:

East west rail line

The Natural Resources region of Alinytjara Wilurara (NRAW) covers almost a third of the state of South Australia, extending from the Western Australian border east to around Nundroo, before heading along the dog fence, encompassing Yellabinna /Yumbarra regional reserve towards Tarcoola including the eastern section of the Great Victoria Desert (GVD), and then north, capturing Tallaringa Conservation Park and the Anangu Pitjantjatjara Yankunytjatjara Lands (APY). Within much of the APY, buffel grass has become firmly established, outcompeting native species due to its rapid growth, quick recovery after fire, and rapid dispersal of seeds. However, across the remainder of the NRAW region, buffel grass is only recorded in smaller tracts, mainly along transport corridors such as highways and rail lines. As such, a large scale initiative for NRAW is the Buffel Free GVD project, which aims to maintain the areas such as the Yellabinna/Yumbarra and Maralinga Tjarutja lands as a buffel grass free zone.

At present, road access within the GVD is relatively limited, with only a small number of business roads and one relatively low frequency 'tourist track' crossing the areas. To date, many of these roads show very little ingress of buffel grass, with small pockets being found and treated relatively successfully. However, the biggest risk for the movement of buffel grass is the East-West rail line, from Port Augusta West towards Perth, intersecting the GVD from around Lyons Siding to past Ooldea Siding before heading across the Nullarbor.

This particular rail line is a busy freight line, as well as offering some passenger services, as it is the direct link between Sydney and Melbourne to Perth. Its relationship to buffel grass is due to the trains coming into contact with buffel grass as they pass through areas such as Port Augusta or more recently Tarcoola, both of which have well established populations of buffel grass. Trains then carry the buffel grass seed within the 'cow catcher', with seeds being dispersed from the catcher when the train turns a corner, due to changing airflows and thus blowing seeds out onto the verge. This can be shown when accessing the rail line as the majority of buffel grass tends to be found on the corners of the track. Trains are as such one of the primary vectors for the transport of seeds along this line, however ARTC work vehicles (trucks, loaders and graders) all move along the access track from areas with buffel grass, as well as public, with the road also frequently used by people travelling from APY Lands to Oak Valley or Yalata. The combination of these vectors has resulted in the dispersal and slow progression of the species west into areas previously buffel grass free. As such the rail line corridor provides a weak link in keeping buffel grass out of the GVD, due to the relentless and constant risk of seeds being pushed along the length of the train line. Therefore, this rail line has become a priority zone for the NRAW in the fight against buffel grass.

This rail line corridor has been monitored and treated for buffel grass since 2009, with annual trips of up to three days undertaken by two NRAW staff. However, since 2011 buffel grass works in the rail corridor have aimed to increase monitoring and escalate treatment of buffel grass along the rail line corridor in response to the noted increase in the spread and abundance of buffel grass. These have been facilitated by NRAW, using up to four staff, as well as employing approximately two to four community members. These large scale trips have occurred at a yearly rate, and take around six days for completion. In addition, smaller, two to three day trips are undertaken by NRAW staff, at a frequency of approximately three per year. NRAW also employed a private contractor, undertaking around four trips along the rail line in 2017 (which take around four days each trip). These surveys also involve at least one community member to undertake identification of buffel grass as well as the subsequent treatment of the plants.

All trips are undertaken by vehicle, such as a 4WD ute fitted with a boom spray unit, and for the larger trips up to two light utility vehicles also fitted with spray reels. In addition, workers also carry backpack units so that they can access small isolated outbreaks that hoses cannot reach from vehicles or outlier plants in the scrub. This 278 km of maintenance track and rail line corridor includes approximately a 30km buffer to the east of Lyon, extending to Malbooma Siding, to provide extra protection into tracks such as Googs Track. It must also be highlighted that gaining access to the rail line corridor takes a full day of travel, due to limited track access (Googs Track and Oak Valley Road) and the vast Yellabinna Yumbarra Conservation Park, limiting access to either Ooldea or Malbooma.

All outbreaks are mapped by simple GPS or as the case in 2013 and 2016, use of data logger, while buffel grass was treated. The data logger allows for a relatively accurate reading of number of plants in a rapid fashion as it is set up with only five buttons to assess populations. These buttons are set to record five different criteria; 'less than ten plants' 'less than 20 plants', 'less than 30 plants', 'less than 40 plants' and 'more than 50 plants' the only options. Each time any data are logged a GPS fix is also taken, which can then be mapped to allow visualization of the condition of the corridor. Each input is restricted to populations that were separate to each other, with a gap of at least a metre being the standard. However, with some of the larger populations (a few hundred plants) a different approach was required, with a best estimate made of the population (i.e. numerous records when walking and treating each 50 for example).

Many of the initial trips in 2009 mapped outbreaks and then treated the plants generally with just glyphosate. However, it was noted in May 2016 that many of the

Buffel grass infestations along the railway line

known populations of the weed had increased, and a different treatment method was required. As such, a combination of glyphosate and flupropanate have been used since May 2016 (flupropanate being a residual herbicide to prevent germination of new recruits).

Monitoring in October 2016 showed strong results from the treatment undertaken in May 2016, showing it to be far more successful than glyphosate alone. Many of the larger populations of buffel grass were succumbing to this treatment mix, with only single or very few plants being noted in these areas after follow up monitoring. We are yet to establish the viability of seed in or adjacent to these populations. In February to May 2017 treatment of the remnant populations continued, this time with the addition of pine oil to the treatment mix, in an attempt to also kill any seeds that may be persisting on plants or on the soil surface. Again it is too early to determine the efficacy of the pine oil, however monitoring will continue through the summer.

Inspections undertaken in October 2017indicated that very little of the known populations of buffel grass that were treated initially in May 2016 and subsequently in early 2016 and 2017 had re-established between Ooldea and Malbooma; again suggesting that the current combination treatment method employed is potentially having the desired effects. Unfortunately, recent inspections noted that at Watson (further to the west into the Nullarbor) a large outbreak was present in an area which was believed to have been last treated in late 2015/early 2016. However it appears that this germination and subsequent growth event was actually missed, due to some communication breakdowns and staff turnover. This has since been re-treated and is being monitored. It highlights the need for clear and concise communication methods, which are robust and can handle staff turnovers etc. to ensure that these types of events are treated properly. In addition, and despite the all the works between Ooldea and Malbooma, concerted efforts will need to be continued further along the line to ensure that any spread does not continue along the line further west of the current targeted area. This may need to be added to the program trips, with the addition of another day or two, extending the intensive monitoring from Malbooma to Watson or Cook. From October 2017 monitoring efforts have extended to at least Watson, and should assist in limiting any outbreaks that may sneak through undetected into the Nullarbor.

It should also be noted that at present ARTC provide access to the rail line to perform the inspections and control, as well as notifications of any significant outbreaks that they have observed.

4.11 Control options

There are considerable challenges to the control of buffel grass in northern South Australia: its physiological and ecological characteristics; its widespread geographic distribution; the extensive area infested; the land use present; and community awareness regarding impacts of this species (Greenfield 2007). In addition, spread by wind and water can potentially move buffel seed many kilometres in a single event.

Information on the distribution of buffel grass, including where control works have been completed, is critical to support planning. The degree of detail required varies with the scale and purpose of planning actions, for example planning in eradication areas with scattered plants requires knowledge down to single plant level.

Once established there is no single control method available for the successful management of buffel grass over extensive areas. Prevention is the most cost-effective means of weed control. It is important therefore to keep currently uninfested areas free of buffel grass, particularly near high value assets.

As the current extent of buffel grass in northern South Australia precludes absolute control, effort needs to be guided by decision making based on biodiversity values and other assets potentially at risk, logistics, and available resources.

Information on best practice control techniques, chemicals and biological control can be found at the PIRSA website.

Chemical and mechanical methods, and in some situations fire, can be used in an integrated control program for buffel grass. All methods may be effective in particular situations depending on the infestation density and extent, terrain, resources, and the management objectives (e.g. eradication or containment). Control programs require several years of follow-up that may increase the cost several-fold; in some situations the long-term costs can make control of large dense infestations uneconomic.

Roadside outlier control near Port Pirie as part of Strategic Response collaboration among regions.

Without intensive follow-up control, buffel grass will persist, and usually dominate, post-fire communities. Fire may be used to reduce biomass before herbicide treatment of regrowth, but if used alone is unlikely to remove the seed bank when seed is buried even under shallow soil. Further research on buffel grass fires is necessary to define the fuel and fire characteristics required to effectively reduce aerial and soil seed banks (Tschirner 2016).

Buffel grass must be actively growing for effective uptake of herbicides. In arid or semi-arid regions of South Australia the period of active growth is unpredictable and may be short-lived, and timing is therefore very important for control. Foliar application of select herbicides to young plants or regrowth following rain provides the best opportunity for success. Simple physical removal of buffel grass may be considered for new, small infestations, particularly where the plants are bearing seed and the plants are not in an active growth phase. Fire or slashing and herbicides may be integrated to improve foliar uptake and to manage larger infestations.

The high cost of herbicides and associated labour is a hindrance to control. All control programs require several years of follow-up treatment and monitoring, which further increases the cost. Control and eradication of infestations must be carried out on all tenures including government and Aboriginal lands.

Biological control is considered the most cost effective management method for dense areas of many weeds. However, as buffel grass is recognised as a valuable forage species in some parts of Australia, the potential use of biological control agents would require extensive and extended engagement with all interested parties to identify common ground, and is unlikely to gain acceptance in the term of this plan. There are no approved biocontrol agents in Australia for buffel grass, but it is affected by several diseases, and an insect pest. The most important diseases are buffel blight, caused by fungal pathogen *Pyricularia grisea*, and ergot (*Claviceps* spp.) affecting seed production (Perrott 2000). A condition known as buffel grass dieback in areas of central Queensland has been described but the causal agent(s) are unknown (Makiela *et al.* 2008). The buffel grass seed caterpillar (*Mampava rhodoneura*) is the only documented major insect pest of buffel grass. It has been recorded in warmer, higher rainfall areas of Queensland.

The range of options that may be considered for the control of buffel grass in South Australia are presented in Appendix 3.

Herbicide control

Buffel grass must be actively growing for effective uptake of herbicides. Foliar application of select herbicides to young plants or regrowth following rain provides the best opportunity for success.

Timing is critical to successful chemical control. Re-sprouting plants can flower within a week after rain and new germinations can set seed within three to six weeks with sufficient moisture (Dixon *et al* 2002). As a general rule, foliar herbicides should be applied after rainfall when the plant is actively growing and before seed set. Well-developed rootstock may mean that two or three sprays are required to destroy large plants (Dixon et al 2002) and seeds can remain viable for up to four years (Winkworth 1971). Chemical control programs thus require flexibility and responsiveness around rainfall events and monitoring and follow up control is required for an extended period to ensure eradication.

There are 90 products registered in South Australia that can be used for the control of buffel grass. (PUBCRIS search, July 2019).The minor use permit PER9792 permits the use of four other hebicides. The following table summarises the advantages and disadvantages of each herbicide.

Herbicides registered or permitted for use on buffel grass.

Herbicide	Advantages	Disadvantages
Active Ingredient Diquat present as diquat dibromide / paraquat present as paraquat dichloride Example of Registered Product Conquest Scorcher 250® Pacific Diquat/Paraquat 250® plus other registered products	• fast action, may be useful in burning seed heads off (to control seed set) if sprayed late.	• classed as moderately toxic (S7) to humans (LD50 by skin absorption is 260 mg/kg male rabbit). Not safe for general use. • toxic to fish and wildlife also • only burns the top off the plants • registered for this use in SA, but buffel grass is not on the label.
Active Ingredient Haloxyfop-p present as the haloxyfop-p-methyl as the only active constituent. Example of Registered Product Verdict 520 Herbicide ® Convict Herbicide® plus other registered products	• not residual (degrades within 24 hours) therefore will not prevent regrowth of competitive native plants.	• classed as slightly hazardous to humans (S6) • available for use under APVMA permit PER 9792.
Active Ingredient 360, 450 or 540 g/L glyphosate present as the isopropylamine salt as their only active constituent. Example of Registered Product Nufarm 360 Herbicide ® Roundup Biactive Herbicide ® plus other registered products	• relatively safe (S5) for general use by a broad range of people • not residual therefore will not prevent regrowth of competitive native plants • a general use herbicide that can be used on a range of weeds • Roundup Biactive is registered for use in waterways • can be mixed with flupropanate herbicides.	• 80% kill rate (Dixon *et al.* 2002) • available for use under APVMA permit PER 9792.

[4] A glyphosate – flupropanate-pine oil mix (e.g. Roundup Power-Max® Tussock® and BioWeed®), has provided the most effective long term control in most situations when applied correctly.(Pers. Comm., T. Bowman, PIRSA).

Herbicide	Advantages	Disadvantages
Active Ingredient 745g/L flupropanate present as the sodium salt as the only active constituent. Example of Registered Product Taskforce Herbicide ® Tussock Herbicide ® plus other registered products	• residual herbicide is good for areas such as roadsides and fence lines • good results achieved. • prevents survival of a majority of new germinations • reduces seedbank • can be mixed with glyphosate herbicides.4	• classed as slightly hazardous to humans (S6) • residual herbicides may prevent regrowth of competitive native grasses. • available for use under APVMA permit PER 9792.
Active Ingredient 128 or 212g/L fluazifop-p present as the butyl ester as their only active constituent. Example of Registered Product Fusilade Forte 128 ec Herbicide plus other registered products	• low persistence and mobility in soils (half-life of 1 week) therefore will not prevent regrowth of competitive native plants • may only control seedlings (Pers. Comm., I. Honan, DEW).	• classed as slightly hazardous to humans (S6) • ester formulations are relatively volatile with a greater chance of off target damage • moderately toxic to fish • available for use under APVMA permit PER 9792.
Active ingedient 86.9g/kg flupropanate present as the sodium salt as the only active constituent. Example of Registered Product GP Flupropanate Granular ®		• registered for this use in SA, but buffel grass is not on the label.
Active Ingredient 680g/L alpha terpineol as pine oil Example of Registered Product Bioweed™ Organic Herbicide Concentrate	• is suitable for use on organically certified properties • can be mixed at 2% with glyphosate and flupropanate to destroy buffel grass seed.	• not proven to control mature buffel grass tussocks • buffel grass is not on the label • registered only for nonselective weed control in orchards, vineyards, commercial, industrial and public service areas, around agricultural buildings and other non-crop farm situations.

When using herbicides, it is important to follow safe use instructions on herbicide labels. Refer to product label for full conditions of use and application instructions. Some of the herbicides are soil active residuals and must be used with care to minimise damage to native vegetation.

In remote locations where follow up control is less likely to occur, the use of granular applied residual herbicides for isolated small infestations or single plants can be an alternative to mechanical grubbing (Greenfield 2007). Off-target impacts to native vegetation that could effectively compete with buffel grass need to be considered with this method. More research into other potential herbicides for buffel grass control is required.

Friedel *et al.* (2009) provide an example of the costs involved in the chemical control of buffel grass for a project conducted at Alice Springs Desert Park, NT between 1997 and 2007, indicating the very high cost of control in arid regions. The cost of labour and materials for herbicide spraying varied from almost $10,000/ha in 2000 in the initial stages of the project, to $50/ha in 2006 for regular follow-up spraying of buffel grass after rain events once the buffel grass was largely under control. Over the 10-year period (1997-2007) the average cost was $5500/ha.

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Appendix 1

Knowledge gaps and directions for future investigation and research on buffel grass in South Australia (refer Action 4.4)

Key areas	Activity
Farming	• identify low-risk alternatives to buffel grass in rangelands and pasture, including native species.
Impacts	• evaluate long-term outcomes on productivity and pasture sustainability • identify adverse long term impacts on biodiversity (e.g. competition with native plants, effect on fauna, and effect of changed fire regimes), pastoral production (e.g. change in fire risk, loss of native forage species) and infrastructure (e.g. change in fire risk).
Management / control	• investigate potential for fire as a component of integrated weed management for small and large infestations • apply new knowledge of functional differences between varieties, germination requirements and seed longevity to improved management • investigate cost-effective options for control of buffel grass on organic certified properties. • continue to review, monitor and communicate the effectiveness of herbicides such as granular flupropanate and pine oil • promoting and monitoring ecosystem recovery following buffel grass management.
Current distribution	• continue to coordinate the development of a GIS layer of buffel grass distribution (including estimates of abundance /densities) and integrate data from different systems to enable uniform statewide monitoring and reporting • improve understanding of the distribution and habitat requirements of *C. pennisetiformis* • where available, utilise the satellite data, aerial surveys and ground validation to monitor and search for buffel grass infestations in large and inaccessible areas. Investigate / refine / apply survey methods able to detect low densities of buffel (hence early stages of invasion) acknowledging changes in technology.
Potential distribution	• predictive spatial and/or habitat modelling at a range of spatial scales (state, regional, local), refined to identify environments prone to buffel grass infestation • identify physical aspects such as climate and soil; biotic factors such as competition from other grasses, tree cover, effects of herbivores – to determine limitations on potential distribution, preferred habitats and mechanisms of invasion • identify areas of high biodiversity value (e.g. areas of high diversity, threatened species, endemism, or ecological integrity) at greatest risk of invasion based on environmental preferences of buffel grass.
Ecology	• identify habitat preferences, e.g. soil, invaded vegetation, disturbance regime, and consider possible differences between buffel grass varieties • determine potential for establishment in different environments by natural or unassisted forms of dispersal • fire ecology: effect of buffel grass infestations on the fire-proneness of different plant communities - e.g. changes to fuel loads, burn severity and potential for buffel grass–initiated positive fire-invasion feedback • determine seed bank longevity - predict how long seeds will persist in different soils – consider potential varietal differences • monitor ecosystem recovery after buffel grass control to identify strong native potential competitors, underlying drivers and thresholds that facilitate restoration • impacts of native detritivores and potential biocontrol agents.
Taxonomy	• genetic analysis of buffel grass varieties in SA to determine whether there is any association of genotypes with particular landscapes, determine dispersal pathways and enable rapid identification where non-reproductive material or seedlings is collected • evidence of hybridisation and adaptation in South Australia.

Appendix 2

Isolated roadside and township infestations of buffel grass recommended for priority control based on a survey of outback roads undertaken 2010 - 2015 (Shepherd, 2011 Bowman, 2014 and Harvey, 2015).

Priority roadside occurrence (based on isolation)	Description of occurrences/ notes	Potential buffel grass free zone being protected
Roadside at Kokatha and Lake Everard Stations (Gawler Ranges)	• small populations and one single occurrence mainly confined to the roadside disturbance zone with three locations where the plants extend into the natural zone.	• prevent roadside spread into the Gawler Ranges (primarily by graders) from the Glendambo to Tarcoola Road populations • maintain the Gawler Ranges buffel grass free.
Roadside at Corunna Station (Gawler Ranges)	• a small population confined to the disturbance zone • small sparse populations of buffel grass are likely to be present on the Pt Augusta to Iron Knob road .	• prevent spread into the Gawler Ranges from Lincoln Highway infestations • maintain the Gawler Ranges buffel grass free.
Roadside at Mt Eba and Mt Vivian Stations (north of Glendambo)	• numerous small populations mainly confined to the roadside disturbance zone with a number of small infestations where the plants extend into the natural zone.	• prevent roadside spread from the Stuart Highway populations • maintain all roads running east from the Stuart Highway buffel grass free.
Roadside on the William Creek to Coober Pedy Road, 63km from Coober Pedy.	• a small clump of plants confined to the roadside disturbance zone.	• maintain all roads running east from the Stuart Highway buffel grass free.
All occurrences on the Oodnadatta Track from William Creek to Marree	• six known small occurrences.	• prevent roadside spread along the Oodnadatta Track • maintain the Oodnadatta track, between Marree and William Creek buffel grass free.
All occurrences on the Bore field Road	• small infestations along the road and pipeline.	• contain spread in Zone 2
Roadside on the Strezelecki track, 17km east of Lyndhurst.	• a small population confined to a large culvert • closest other existing records are 20km east along the Strezelecki track in a drainage line.	• prevent roadside spread along the Strezelecki Track from Frome (and nearby) creek populations.
Arkaroola visitor centre.	• several other existing records close by.	• prevent spread by vehicles from high visitation areas. • promote awareness and control by the Arkaroola managers

Priority roadside occurrence (based on isolation)	Description of occurrences/ notes	Potential buffel grass free zone being protected
Roadside on the Quorn and Parachilna Road - excluding the area around the Brachina Creek and Brachina Gorge turn off.	• Four small populations confined to the disturbance zone. One population/clump 4.5 km north of Quorn the other 3 populations/ clumps 2.5, 22 and 30km north of Hawker • larger populations of buffel grass were also mapped at the Brachina Gorge turn off, in the Brachina Creek and in Commodore Swamp These populations are listed under the heading *Locations where buffel grass was widespread in the natural zone.*	• prevent spread into the Flinders Ranges.
Quorn to Wilmington Road	• two medium size infestations still contained within the road corridor.	• control known infestations in Zone 3.
Glendambo, Tarcoola, Barton, Ooldea	• small clumps are present around Glendambo, Barton and Ooldea with significant infestations around the Tarcoola township and along the rail corridor from Kingoonya to West of Tarcoola	• prevent further spread from high visitation areas into AW NRM, Yellabinna Regional Reserve, Gawler Ranges.
All occurrences along the Aboriginal business road from Oak Valley to the WA Border	• small clumps limited to the road corridor with two occurrences that extend into the naturalized zone.	• prevent spread into the Great Victoria Desert.
Tallaringa Conservation Park	• one small roadside clump in the Eastern end of Tallaringa Conservation Park.	• prevent spread into the Great Victoria Desert.
Lochiel rest area	• small medium density infestation on the roadside, extending into the naturalised zone adjacent to the Lochiel rest area.	• control known infestations in Zone 3 and prevent spread.
Port Wakefield Road and Northern Expressway	• small isolated clumps along the Port Wakefield rd. and Northern Expressway	• control known infestations in Zone 3.
Port Adelaide Container Terminal	• high priority infestation for control given the movement of containers around the state.	• prevent the movement of contaminated good within the state.

Appendix 3

Summary of management options for buffel grass

Management Option	Description	Advantages	Disadvantages
Prevention - actively prevent deliberate introductions	Limit introduction and spread of buffel seed by preventing introduction of contaminated vehicles, produce, animals, soil, machinery, etc. Prohibit propagation under NRM Act	• cost effective • no need to use herbicides • likely to be sucessful for smaller strategic sites where maintenance is achievable.	• difficult to justify and implement when such practices are not generally employed for other pest plants • requires vehicle washdown facilities – may be expensive to install and maintain • voluntary use of washdown facilities by community likely to be low • compliance activities are expensive.
Mechanical	Grubbing or digging out	• effective for small isolated patches • Mowing can stimulate regrowth that is more effectively killed by spraying • can be done any time of year (e.g. dry conditions when other methods unsuitable) • can be done by unskilled persons • no chemicals required.	• labour intensive and costly • unsuited as a single method for extensive areas, but combined with another method may improve efficacy (e.g. mow and spray regrowth) • ongoing hand pulling and herbicide treatment of regrowth is required • soil disturbances can stimulate seed germination and enhance seedling establishment (though can also stimulate native spp.) • may need to destroy removed plants to avoid further spread
Fire	Burn and follow up treatment of regrowth with herbicide applications	• herbicide spray regrowth gives good results • burning stimulates regrowth • reduces seed bank • burning stimulates and provides uniform regrowth for follow up chemical control.	• fire is not an effective management tool on its own • can stimulate buffel grass growth over native species • herbicide treatment of regrowth is essential • equipment and clean water needed for herbicide application • risk of fire escape.
Herbicide – foliar spray (refer Table 5)	Foliar spray when actively growing	• minimal soil disturbance. • can be very effective with follow up control. • can be cost effective on large and dense infestations • may be an effective follow up at sites cleared by mechanical removal.	• buffel grass must be actively growing for effective uptake of foliar spray • brief opportunity for chemical application – timing is critical • Two or three sprays may be required to control large plants • residual herbicides may impact non-target and/or competitive species • efficacy is dependent on good quality water – may not be readily available in remote outback areas.
Herbicide-Residual (refer Table 5)	Application of residual herbicide prior to or during active growth.	• can be applied prior to active growth • significantly reduces the amount of follow-up control due to seedling suppression • some residual products (granular) don't require water for application.	• requires sufficient rain to wash herbicide into the root zone • slow acting/possible seed production in the short term • heavy rainfall events can wash the herbicide out of the root zone • granular product application rates still being refined trough targeted trials.

Management Option	Description	Advantages	Disadvantages
Herbicide – Residual and folia (refer Table 5)	Mixture of foliar and soil active residual herbicide (Glyphosate/ Flupropanate)	• prevents seed production in the short term, control of mature tussocks and suppression of new germinations for approximately 18 months • can be mixed with BioWeed to reduce seed bank.	• non-selective.
Herbicide – Pine oil (refer Tabel 5)	Contact herbicide said to destroy seed on contact (aerial and soil surface)	• organically certified • reduces the seed bank • can be mixed with foliar and soil active residual herbicides above.	• not proven to kill mature tussocks (more trials needed) • non-selective • off label : not registered for use in native vegetation or rangeland.
Biological	There are no known biological controls of buffel grass	• potential for ongoing reduction of the impact and spread of buffel grass • highly target-specific and low cost once established • potential to manage landscape-scale infestations.	• unlikely to gain support from pastoral industry at national level • limited international track record on successful biocontrol of grass weeds • high cost of long-term research until an agent is approved for release (typically 10 years).
Ecological	Maintain ground cover and competition from existing veg.	• encouragement of good land management practices has triple-bottom line benefits.	• perceived conflict with grazing as a land use, particularly in arid areas. • insufficient alone to prevent invasion
Pulse grazing	Graze to prevent formation of seed heads	• potential in integrated control strategies (Melzer 2016) • can reduce the soil seed bank, biomass and fire frequency/intensity • reduce competition with native flora.	• difficult to implement selective grazing,in many situations • disturbance by cattle can create favourable conditions for buffel grass establishment.

Appendix 4

Table 1. South Australian fauna of national &/or state conservation significance currently or potentially threatened by buffel grass, sorted in order of conservation status.

APY = Anangu Pitjantjatjara Yankunytjatjara Lands; AUS = Australia; CR = critically endangered; EN = endangered; NSW = New South Wales; NT = Northern Territory; RA = rare; SA = South Australia; ssp = subspecies; TSSR = Threatened Species Schedule Review panel; VU = vulnerable; WA = Western Australia; * = Recommended change in state conservation status by TSSR in 2015-17.

Scientific Name	Common Name	Conservation Status	Reason for status	Why buffel grass is a threat	Reference / Information
Liopholis kintorei	great desert skink / tjakura	VU (AUS) EN (SA) CR (TSSR*)	Seven isolated locations spread across WA, NT and SA; approximately 6000 individuals. In SA, estimated < 250 and declining, in very small (< 50) populations.	Ongoing spread of buffel grass, and the subsequent likelihood of more frequent wildfires, will change the habitat structure, particularly the open feeding grounds known to be important for tjakura.	National Recovery Plan http://www.environment.gov.au/biodiversity/threatened/publications/recovery/great-desert-skink/index.html; TSSR (2015); E. Ryan-Colton, pers. comm. (2017)
Petrogale lateralis ssp. *lateralis* (McDonnell Ranges race)	black-footed rock wallaby / warru	VU (AUS) EN (SA)	Known mostly from sthn NT (Central Ranges), central eastern WA and APY. Estimated 250 individuals in SA.	Buffel grass promotes hot wildfires which can destroy fire sensitive vegetation, such as figs (*Ficus brachypoda*) and spearwood (*Pandorea doratoxylon*) that are important food sources for warru. Buffel grass already surrounds two warru populations and its uncontrolled spread would threaten other sites.	Warru Recovery Plan (Read and Ward 2011); TSSR (2015); E. Ryan-Colton, *pers. comm*. (2017)
Leipoa ocellata	malleefowl / nganamara	VU (AUS) VU (SA)	Known from NSW, Victoria, SA and WA. An observed > 30% decline in SA in the last 3 generations.	Continued invasion of buffel grass into arid mulga / minyura woodlands and shrub lands and mallee woodlands will increase the fire frequency, removing key food plants and habitat in which they build their mounds.	TSSR (2015); S. Gillam, National Malleefowl Recovery Team, *pers. comm.* (2017)
Eremiornis carteri	spinifex bird	EN (SA)	Estimated < 250 individuals in SA.	Quality spinifex important; habitat decline due to buffel grass spread.	TSSR (2015)
Geophaps plumifera	spinifex pigeon / plumed pigeon	RA (SA)	Estimated < 3000 mature individuals in SA.	Lives in spinifex, which is being replaced by buffel grass on hills and in rocky gorges and creek lines, causing a change in habitat structure and ood availability.	TSSR (2015); E. Ryan-Colton, *pers. comm*. (2017)

Scientific Name	Common Name	Conservation Status	Reason for status	Why buffel grass is a threat	Reference / Information
Pezoporus occidentalis	night parrot	EN (SA)	Likely to occur in SA.	Occurs in spinifex; habitat quality in decline due to buffel grass spread.	Murphy *et al.* (2018)
Chlamydera guttata	western bowerbird	RA (SA)	< 3000 mature individuals in SA; restricted area of occupancy.	Habitat quality is in decline due to the spread of buffel grass.	TSSR (2015)
Ctenotus grandis	giant desert ctenotus	RA (SA)	Restricted distribution and area of occupancy in SA.	Occurs in spinifex; habitat quality in decline due to buffel grass spread.	TSSR (2015)
Ctenotus piankai	paleface ctenotus	RA (SA)	Restricted distribution in SA.	Spinifex obligate; habitat quality in decline due to buffel grass spread.	TSSR (2015)
Varanus brevicauda	short-tailed pygmy goanna	RA (SA)	Restricted distribution in SA.	Occurs in spinifex; habitat quality in decline due to buffel grass spread.	TSSR (2015)
Carlia triacantha	desert rainbow skink	EN (TSSR*)	Restricted and declining distribution in SA, < 5 locations, declining habitat quality.	Prefers large spinifex clumps; threatened by buffel grass spread.	TSSR (2015)
Crenadactylus ocellatus	clawless gecko	EN (TSSR*)	Restricted and declining distribution in SA, < 5 locations, declining habitat quality.	Prefers spinifex; habitat quality in decline due to buffel grass spread.	TSSR (2015)
Amytornis purnelli	dusky grasswren	VU (TSSR*)	< 10 locations in SA; continuing decline in habitat quality.	Breeds in spinifex, which is being replaced by buffel grass on hills and on the sand plains.	TSSR (2015)
Ctenotus ariadnae	pin-striped ctenotus	RA (TSSR*)	Restricted distribution in SA.	Occurs in spinifex; habitat quality in decline due to buffel grass spread.	TSSR (2015)
Ctenotus dux	narrow-lined ctenotus	RA (TSSR*)	Restricted distribution in SA.	Occurs in spinifex; habitat quality in decline due to buffel grass spread.	TSSR (2015)
Delma nasuta	Centralian snake-lizard	RA (TSSR*)	Restricted area of occupancy in SA.	Spinifex obligate; habitat quality in decline due to buffel grass spread.	TSSR (2015)
Diporiphora paraconvergens	western grey-striped dragon	RA (TSSR*)	Restricted distribution in SA.	Occurs in spinifex; habitat quality in decline due to buffel grass spread.	TSSR (2015)

Table 2. South Australian flora of national &/or state conservation significance currently or potentially threatened by buffel grass. Sorted by conservation status.

*APY = Anangu Pitjantjatjara Yankunytjatjara Lands; AUS = Australia; AW = Natural Resources Alinytjara Wilurara Region; CR = critically endangered; DEW = Department of Environment and Water; EN = endangered; EP = Natural Resources Eyre Peninsula Region; EPBC = Environmental Protection and Biodiversity Conservation Act; N&Y = Natural Resources Northern and Yorke Region; NT = Northern Territory; Qld = Queensland; RA = rare; SA = South Australia; SAAL = Natural Resources South Australian Arid Lands Region; ssp = subspecies; TSSR = Threatened Species Schedule Review panel; var = variety; VU = vulnerable; WA = Western Australia; * = Recommended change in state conservation status by TSSR in 2015-17.*

Scientific Name	Common Name	Conservation Status	Reason for status	Why buffel grass is a threat	Reference / Information
Acanthocladium dockeri	spiny daisy	CR (AUS) EN (SA) CR (TSSR*)	Only 6 remnant populations, all clonal.	Not currently a threat; however all remnant populations are found on roadsides in N&Y Region. If buffel grass invaded any of these sites it would outcompete spiny daisy and become a serious threat.	D. Bickerton, Spiny Daisy Recovery Team, pers. comm. (2017)
Haloragis eyreana	prickly raspwort	EN (AUS) EN (SA)	< 600 km^2 extent of occurrence and declining. < 120 km^2 area of occupancy and declining. ≤ 5 locations, decline in habitat quality.	Not currently a threat; however all remnant populations are found on roadsides in EP Region.	D. Bickerton, DEW, pers. comm. (2017)
Prostanthera nudula	naked mintbush	VU (AUS) VU (SA)	Sw NT & APY. In SA, a small number of populations the APY Lands. Area of occupancy < 100 km^2.	Sensitive to fire, threatened by the increased intensity and frequency of fires fuelled by buffel grass on hills.	EPBC Conservation Advice: http://www.environment.gov.au/biodiversity/threatened/species/pubs/7091-conservation-advice.pdf
Acacia latzii	Latz's wattle	VU (AUS) RA (SA) VU (TSSR*)	Restricted to two disjunct areas 200 km apart: sthn NT & nthn SA (2 locations near NT border in SAAL). Localised in SA, < 1000 plants.	A slow growing species, sensitive to fire. Requires low fire frequencies, and therefore threatened by increased intensity and frequency from buffel grass fires.	*National recovery plan:* http://www.environment.gov.au/resource/national-recovery-plan-threatened-acacias-and-ricinocarpos-gloria-medii-central-australia*; TSSR (2015)*
Teucrium grandiusculum ssp. *grandiusculum*		VU (SA)	Endemic to central ranges, highly localised.	Found on rocky slopes that are not currently invaded by buffel grass, but potentially could be in the near future.	TSSR (2016); E. Ryan-Colton, *pers. comm.* (2017)
Stylidium inaequipetalum		VU (SA) RA (TSSR*)	Restricted distribution and area of occupancy in SA.	Found on flood-outs and creek lines in rocky hills, which will potentially be invaded by buffel grass in the future	TSSR (2016); E. Ryan-Colton, *pers. comm.* (2017)

Scientific Name	Common Name	Conservation Status	Reason for status	Why buffel grass is a threat	Reference / Information
Acacia symonii	Symon's wattle	RA (SA) VU (TSSR*)	Difficult to find, small relictual populations, < 1000 plants, limited extent of occurrence.	Botanical experts consider buffel grass and fire a threat. Buffel grass is invading the creek lines and alluvial flats at the base of hills where this species occurs. This invasion could fuel more frequent and intense wildfires that escape into the hill country, threatening *A. symonii*.	TSSR (2015). E. Ryan-Colton, *pers. comm.* (2018)
Acacia tenuior	Central Ranges wattle	RA (SA) VU (TSSR*)	Restricted to high peaks in AW Region. < 1000 plants and 3 locations in SA.	Buffel grass promotes inappropriate fire regimes. The ongoing invasion of buffel grass will outcompete this species and increase fire frequency and intensity, posing a threat to small and isolated endemic plant populations.	Paltridge *et al* (2009); TSSR (2015)
Basedowia tenerrima		RA (SA) VU (TSSR*)	Records from Biological surveys in 1998 indicate very restricted distribution. ≤ 5 known locations in SA.	Buffel grass and fire considered to be a threat.	TSSR (2015)
Acacia ammobia	Mount Connor wattle	RA (SA)	Relatively abundant in sw NT, but mostly restricted to the Mt Connor / Uluru area of the Central Ranges Region. Only 1 known location in SA, in APY.	Highly sensitive to fire - killed by the mildest of fires and populations would require a fire frequency of more than 25 years. Buffel grass promotes very hot fires and invasion of buffel grass poses a threat long-term.	Paltridge *et al* (2009); TSSR (2015)
Dampiera roycei		RA (SA)	Restricted distribution in SA.	Found in spinifex country in nw of APY Lands, where buffel grass is expanding through sand plain habitat, and could outcompete this species or promote inappropriate fire regimes.	TSSR (2016); E. Ryan-Colton, *pers. comm*. (2017)
Goodenia brunnea	Central Ranges goodenia	RA (SA)	Endemic to Central Ranges, mostly APY, but also sw NT. Restricted distribution and area of occupancy in SA.	A primary successional plant following fire. If buffel grass becomes the dominant successional species, Goodenia brunnea will be out-competed.	Paltridge *et al* (2009); TSSR (2016)

Scientific Name	Common Name	Conservation Status	Reason for status	Why buffel grass is a threat	Reference / Information
Hibbertia glaberrima	Central Australian guinea-flower	RA (SA)	APY Lands. Restricted distribution and area of occupancy in SA.	Occurs in a similar habitat to Prostanthera nudula in crevices on granitic outcrops and ranges. Buffel grass is expanding up these hills, and could promote inappropriate fire regimes for fire sensitive species or outcompete this species for space.	TSSR (2016); E. Ryan-Colton, *pers. comm*. (2017)
Melaleuca fulgens ssp. *corrugata*	wrinkled honey myrtle	RA (SA)	Endemic to the Central Ranges; found in sw NT, central east WA and SA (APY Lands). All APY populations surveyed contain very few individuals and are under threat from inappropriate fire regimes. Area of occupancy in SA < 5 km^2 with < 2500 mature individuals.	The ongoing invasion of buffel grass will outcompete this species and increase fire frequency and intensity, posing a threat to small and isolated populations. Currently the species is at high altitude amongst bare rock or fire shadow habitats, but large wildfires promoted by buffel grass at lower elevations may expand into this species habitat range.	Paltridge *et al* (2009); E. Ryan-Colton, *pers. comm.* (2017)
Samolus eremaeus	desert samolus	RA (SA)	Limited creek line habitat. Restricted distribution in SA.	Occurs in creek lines, which are subject to severe invasion by buffel grass on the APY Lands. Buffel grass could outcompete this species directly or promote inappropriate fire regimes	TSSR (2016); E. Ryan-Colton, *pers. comm.* (2017)
Acacia aneura var. *macrocarpa*	weeping mulga	VU (TSSR*)	Scattered, ≤ 5 known locations in SA.	Buffel grass and fire are threats. Long-lived but killed by frequent fires.	TSSR (2015)
Nicotiana rosulata ssp. *ingulba*		VU (TSSR*)	NT, SA & WA. Only 2 known records in SA. Restricted.	Buffel is a threat on the wash-out plains (its preferred habitat).	TSSR (2016)
Acacia validinervia	veined wattle	RA (TSSR*)	NT, SA (APY) & WA. Restricted distribution and area of occupancy in SA	Buffel grass is now growing in close proximity to this species, and could fuel more intense fires that threaten isolated populations.	TSSR (2015); D. Bickerton, DEW, *pers. comm.* (2018)
Apowollastonia stirlingii ssp. *stirlingii*	sunflower daisy-bush	RA (TSSR*)	NT & SA (APY). Restricted distribution and area of occupancy in SA.	Buffel grass and fire considered to be a threat.	TSSR (2015)

Scientific Name	Common Name	Conservation Status	Reason for status	Why buffel grass is a threat	Reference / Information
Calostemma abdicatum	Everard garland lily / apita	RA (TSSR*)	Currently only one general locality in Australia, near Mimili in APY Lands; restricted distribution and area of occupancy.	This species occurs along creek lines and in runoff/seepage areas in rocky hills where conditions are moist. Buffel grass is invading this habitat and may outcompete this species for space.	Paltridge *et al* (2009); E. Ryan-Colton, *pers. comm.* (2017)
Comesperma viscidulum	varnished milkwort	RA (TSSR*)	Near endemic to SA, where it is only known from the APY Lands and Yellabinna Reserve. Scattered, not commonly abundant. Restricted distribution and area of occupancy in SA.	Found in sandplain and spinifex habitat, which could become invaded by buffel grass in the future. A large infestation of buffel grass on APY (at Watarru) is uncontrolled and may spread to the locations of this species.	TSSR (2016); E. Ryan-Colton, *pers. comm.* (2017)
Dicrastylis exsuccosa	sand-sage	RA (TSSR*)	Near endemic, SA (APY) & WA. Disjunct populations. Restricted distribution in SA	Buffel grass and fire considered to be a threat.	TSSR (2016)
Grevillea eriostachya	orange grevillea	RA (TSSR*)	Sw NT, WA & SA (APY). Not found in large populations. Restricted distribution and area of occupancy in SA. Under-collected.	Buffel grass and fire considered to be a threat.	TSSR (2016)
Halgania glabra		RA (TSSR*)	Only one known site in SA (APY Lands), mostly in sw NT & WA.	Responds after fire; buffel grass could promote overly frequent fire regimes.	TSSR (2016); E. Ryan-Colton, *pers. comm.* (2017)
Monotaxis luteiflora		RA (TSSR*)	WA and nw SA (Everard Ranges, APY Lands). Only 2 SA records. Restricted distribution and area of occupancy in SA.	Responds after fire; buffel grass could promote overly frequent fire regimes.	TSSR (2016)
Orianthera centralis		RA (TSSR*)	Known from sw NT, WA & SA (APY), where it is restricted to the sandy plain of Mt Lindsey. Disjunct population. Could be under-collected.	A large infestation of buffel grass at Watarru is currently uncontrolled and may spread to the locations of this species.	TSSR (2016); E. Ryan-Colton, *pers. comm.* (2017)
Psydrax ammophila		RA (TSSR*)	Central Australia, naturally uncommon, sparsely distributed. Sandy loam plains, may be under-collected. Limited number of locations in SA.	Buffel grass is spreading to sand plain habitat, and could create inappropriate fire regimes for this species	TSSR (2016); E. Ryan-Colton, *pers. comm.* (2017)

Scientific Name	Common Name	Conservation Status	Reason for status	Why buffel grass is a threat	Reference / Information
Stemodia viscosa	clammy stemodia	RA (TSSR*)	WA, NT, Qld & NW SA (mostly APY Lands). Rocky sheltered gorge habitat within the ranges. Low numbers. Restricted distribution in SA.	Not currently threatened by buffel grass, although buffel could potentially invade the sheltered gorges it inhabits.	TSSR (2016); D. Bickerton & E. Ryan-Colton *pers. comm.* (2018)
Teucrium reidii	showy germander	RA (TSSR*)	Small population sizes and limited distribution. SA endemic: APY Lands & Nthn Flinders Ranges (Arkaroola). Total known population size estimated < 5000.	Buffel grass is encroaching significantly on the two largest known populations. The species is fire sensitive. Inappropriate fire regimes and competition from buffel grass will significantly affect this species' status.	National Recovery Plan for *Olearia macdonnellensis*, *Minuria tridens* (Minnie daisy) and *Actinotus schwarzii* (desert flannel-flower)
Tietkensia corrickiae		RA (TSSR*)	WA, sw NT & NW SA (APY Lands). Hilly or sandy habitat. Restricted distribution and area of occupancy in SA.	Occurs in the far NW corner of APY Lands. In this area buffel grass is encroaching the flats adjacent to where this species has been recorded. Small annual species probably susceptible to changes in soil structure, hydrology and habitat structure brought about by buffel grass invasion.	E. Ryan-Colton, pers comm. (2018); South Australian Seed Conservation Centre Herbarium Sheet.

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Photo credits

Cover: Dense buffel grass infested hills and plains near Umuwa, APY Lands. Photo: Troy Bowman, PIRSA
Cenchrus ciliaris, buffel grass. Photo: Troy Bowman, PIRSA

Aerial herbicide trial, Mambray Creek.
Photo: Grant Roberts, DEW

Rocky hill with pristine *Triodia* grassland.
Photo: Troy Bowman, PIRSA

Rocky hill heavily invaded by buffel grass.
Photo: John Read

Shrubs killed by buffel grass fire, surrounded by a sea of buffel regrowth, APY Lands. Photo: Troy Bowman, PIRSA

Buffel grass invasion in native shrubland.
Photo: Troy Bowman, PIRSA

Buffel grass invading spinifex grassland.
Photo: Troy Bowman, PIRSA

Controlled burn of buffel grass, Umuwa, APY Lands.
Photo: J. Stelmann, DEW

Buffel grass strategic response team, Coober Pedy.
Photo: Troy Bowman, PIRSA

Herbicide trial site (foreground) in buffel grass monoculture, Umuwa, APY Lands. Photo: Troy Bowman

Effective herbicide trial results, Umuwa, APY Lands.
Photo: Troy Bowman, PIRSA

Buffel grass (*Cenchrus ciliaris*) seed heads.
Photo: Troy Bowman, PIRSA

Roadside outlier control near Port Pirie as part of Strategic Response collaboration among regions.
Photo: T. Bowman

Buffel grass fire, Oak Valley, MT Lands.
Photo: Teresa Gurney, DEW

Last page: Rangers from across Western and South Australia after the first Southern Desert Ranger Forum at Ilkurlka. Photo: Arid Lands Environment Centre

Bon Bon case study:

Buffel grass on Stuart Hwy before treatment.
Photo: Mike Chuk

Same site post treatment.
Photo: Mike Chuk

Regeneration after buffel grass control.
Photo: Mike Chuk

Hand removal of buffel grass by volunteers.
Photo: Julia Harris

Bush food case study: *Ili*, one of the most important bushfoods.
Photo: Ellen Ryan-Colton

Thick buffel grass growing under the important bush food wattleseed *Acacia victoriae.*
Photo: Ellen Ryan-Colton

East West rail line case study:
Buffel grass infestations along the railway line.
Photo: Troy Bowman, PIRSA

Great Victoria Desert case study:
Rangers from the APY Lands spraying buffel grass.
Photo: Arid Lands Environment Centre

Warru case study:
Looking after warru on the APY Lands with ranger Jacob MacKenzie.
Photo: Ellen Ryan-Colton

Disclaimer

Rangers from across Western and South Australia after the first Southern Desert Ranger Forum at Ilkurlka.
Photo: Arid Lands Environment Centre