**Australian Government**

**Department of Climate Change, Energy, the Environment and Water**

# Threat abatement plan for ecosystem degradation, habitat loss and species decline due to invasion of northern Australia by introduced gamba grass (*Andropogon gayanus*), para grass (*Urochloa mutica*), hymenachne (*Hymenachne amplexicaulis*), mission grass (*Cenchrus polystachios*) and annual mission grass (*Cenchrus pedicellatus*)

**Consultation Draft 2025**

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# 1  Introduction

## 1.1　Threat abatement plans

The Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) provides for the identification, assessment and listing of key threatening processes. A key threatening process is a process that threatens or may threaten the survival, abundance or evolutionary development of a native species or ecological community.

The Australian Government develops threat abatement plans with input from other levels of government, natural resource managers, scientific experts, First Nations people and other relevant stakeholders and it then facilitates their implementation through partnerships and co-investments.

A threat abatement plan must provide for the research, management and other actions necessary to reduce the key threatening process concerned to an acceptable level in order to maximise the chances of the long-term survival in nature of native species and ecological communities affected by the process. Threat abatement plans for invasive species not only strive for better technical solutions, but also include critical enabling objectives such as:

- addressing social, legal and economic knowledge gaps and barriers

- identifying research priorities

- integrating interests relating to biodiversity conservation with biosecurity and agricultural production and amenity considerations.

Recovery plans and conservation advices for threatened species and ecological communities that are threatened by these invasive grass species may also outline priorities for invasive grass management and research.

Ecosystem degradation, habitat loss and species decline due to invasion of northern Australia by introduced gamba grass (*Andropogon gayanus*), para grass (*Urochloa mutica*), olive hymenachne (*Hymenachne amplexicaulis*), mission grass (*Cenchrus polystachios*) and annual mission grass (*Cenchrus pedicellatus*) was listed as a Key Threatening Process (KTP) under the EPBC Act in 2009.

This threat abatement plan replaces the 2012 plan. It should be read in conjunction with the *Background document for the threat abatement plan for ecosystem degradation, habitat loss and species decline due to invasion of northern Australia by introduced gamba grass (Andropogon gayanus), para grass (Urochloa mutica), olive hymenachne (Hymenachne amplexicaulis), mission grass (Cenchrus polystachios) and annual mission grass (Cenchrus pedicellatus)* (the background document), which provides more information about the biology of these grasses, their ecological and cultural impacts and control methods.

## 1.2    Names and terminology

The current scientific name for each grass species addressed by this plan are in Table 1. There have been changes to the current Australian naming convention for the 2 mission grasses since the key threatening process was listed, and the synonyms along with some of the common names are included within Table 1.

*Hymenachne amplexicaulis* is referred to as hymenachne throughout this plan. There is also a hybrid between the native *Hymenachne acutigluma* and the invasive *Hymenachne amplexicaulis*, which is referred to as *Hymenachne* x *calamitosa*. The native *H. acutigluma* occurs in the Northern Territory (NT) and Queensland (Qld), but not Western Australia (WA) or New South Wales (NSW).

In this plan, the term 'perennial mission grass' is used for *Cenchrus polystachios*. The term 'mission grass' is used when the available information does not differentiate between annual mission grass (*C. pedicellatus*) or perennial mission grass (*C. polystachios*). Gamba grass, perennial mission grass and annual mission grass are all tropical, terrestrial, high biomass, tussock forming grasses, that typically invade woodlands, savannas and riparian vegetation. Para grass and hymenachne are perennial, stolon forming grasses which invade tropical, sub-tropical or temperate wetlands, floodplains and waterways. Stolons are horizontal, above-ground, creeping stems which can form roots and shoots. More details on the biology of these species can be found in Chapter 2 and 3 of the accompanying Background Document. These 5 species are collectively referred to as invasive grasses throughout the plan.

The term waterway is used throughout the plan to indicate any river, creek, stream, including its floodplain, watercourse, drainage feature or estuary. This includes systems that flow permanently, for part of the year or occasionally.

This plan should be read in conjunction with the accompanying Background Document, which provides more information on the biology of these invasive grass species, their ecological impacts and an overview of management options.

**Table 1 Scientific names for the invasive grasses covered in this plan as stated within the Australian Plant Census (APC). Subspecies and hybrids are indicated if they are present in Australia. Common names and synonyms are also stated.**

| Scientific name | Synonyms | Sub species or hybrid | Common names |
|---|---|---|---|
| *Andropogon gayanus* Kunth. Enum. | - | - | Gamba grass |
| *Cenchrus pedicellatus* (Trin.) Morrone | *Cenchrus pedicellatum*  *Pennisetum pedicellatum* (name used in KTP listing) | *Cenchrus pedicellatus* (Trin.) Morrone subsp. *pedicellatum*  *Cenchrus pedicellatus* subsp. *unispiculus* (Brunken) Morrone | Annual mission grass |
| *Cenchrus polystachios* (L.) Morrone. | *Pennisetum polystachyum* (name used in KTP listing)  *Cenchrus polystachion* | - | Mission grass  Perennial mission grass |
| *Hymenachne amplexicaulis* (Rudge) Nees | *Hymenachne pseudointerrupta* | *Hymenachne* x *calamitosa* | Hymenachne  Olive hymenachne |
| *Urochloa mutica* (Forsk.) Nguyen. | *Brachiaria mutica* | - | Para grass  Mauritius grass |

# 1.3 Invasive grass impacts

Invasive alien species are one of the 5 major direct drivers of change in nature, and it is predicted that threats from invasive alien species will increase in the future (IPBES 2023). Over 2,200 species of grass have been introduced into Australia (Cook and Dias 2006). Around 400 of these species have naturalised in Australia (Grice et al. 2013), and approximately 180 species are thought to be invasive (Virtue et al. 2004). Many of these species were deliberately introduced to increase pasture productivity (Cook and Dias 2006). Today most Australian ecosystems are subject to invasion by one or more introduced grass species, with northern Australia having numerous naturalised species that originated from tropical Africa, Asia, and the Americas (Grice et al. 2013).

The grasses included in this key threatening process are transformer species, as they can 'change the character, condition, form or nature of a natural ecosystem over a substantial area' (Richardson et al. 2000). All these grass species have the capacity to dominate the vegetation they invade and alter the resources (e.g. nutrients and light) available to other plant species (Douglas et al. 2004; Rossiter et al. 2004; Sheppard et al. 2010). Following invasion, the plant species richness of the invaded community generally declines (Douglas et al. 2006; Grice et al. 2013), with gamba grass and para grass invasion capable of reducing landscape biodiversity on a scale similar to broadacre agriculture (Godfree et al. 2017). The decline in plant species richness in wetlands invaded by hymenachne and/or para grass can lead to them looking almost like a lawn, with far less open water (Grice et al. 2013; Setterfield et al. 2013; Wearne et al. 2010).

These grasses impact native species and communities through a range of direct (e.g. competition for resources, loss of food source, loss of habitat) and indirect mechanisms. The most common indirect impact on threatened species and ecological communities is via increased fire intensity, frequency

and/or extent (DAWE 2022; Rossiter et al. 2003; Setterfield et al. 2010; Setterfield et al. 2013; Woinarski and Winderlich 2014). The direct impact of these invasive grasses on flora and fauna can also be amplified by their influence on fire.

**Grass fire cycle**

These grasses are all high biomass forming, with their biomass recorded as 2 to 30 times greater than the native vegetation they replace (Douglas et al. 2004; Rossiter et al. 2003; Setterfield et al. 2010; Wearne et al. 2013). The increased fine fuel from gamba grass and the mission grasses, combined with these grasses curing later in the dry season than native grasses, can cause high intensity dry season wildfires. These fires can threaten human safety, property, persistence of native species, and function of ecosystems. Repeated high intensity fires, lead to a reduction in tree and shrub canopy cover, and eventually death of trees, transforming savanna woodlands into grasslands dominated by invasive grasses (Brooks et al. 2010; Setterfield et al. 2010). Fire has a positive effect on invasion and establishment of gamba and the mission grasses. Updraughts from fire can disperse the invasive grass seeds, and intense fire can create bare ground for seedling establishment, remove competing native vegetation and creating more suitable habitat for the invasive grasses.

The positive feedback loop between fire and invasive grass expansion is known as the grass fire cycle (D'Antonio and Vitousek 1992). Another term, the human grass fire cycle, has also recently been used to describe this phenomenon, to indicate the role people have in the introduction and spread of introduced grasses (Fusco et al. 2022). Please see sections 2.1.4, 2.2.3 and 4.1 of the Background Document cover for more information on invasive grass fire interactions.

Para grass and hymenachne invasion can also lead to high intensity fires at the end of the dry season on seasonally inundated floodplains. When the floodplains dry out, dry grass material lodged in wide cracks in the clay soil can sustain a fire, making them hard to control (Cameron 2003). Para grass fires can reach the tree canopy, and lead to death of trees on floodplains (Hannan-Jones and Csurhes 2012).

The increased threat of damaging wildfires that are difficult and costly to control, has been a key driver for increased control of gamba grass in the Northern Territory. The average cost of managing a gamba grass wildfire ($25,609 ± $5,134 in 2017) has been estimated to be 26 times greater than an equivalent native grass wildfire ($938 ± 252) (Setterfield et al. 2018). One gamba grass wildfire near Darwin cost $102,130 to control in a single day in 2017 (Setterfield et al. 2018).

The invasive grasses addressed by this plan threaten 61 EPBC Act listed threatened species including mammals, reptiles, fish, birds, insects and plants (Appendix A). These grasses are also known to threaten at least 2 listed threatened ecological communities. They are a known or potential threat to more than 4 Ramsar wetlands, one National Heritage place and 2 World Heritage sites. More details about the threats posed by these invasive grasses are outlined in Chapter 4 of the Background Document.

Minimising the threats from these grasses will help ecosystems and species to cope with other threats, particular complex threats, such as climate change and inappropriate fire regimes. These 2 threats are addressed in the listed key threatening processes, *fire regimes that cause declines in biodiversity*, and *loss of climatic habitat caused by anthropogenic emissions of greenhouse gases*.

Climate change interacting with land use change is predicted to amplify the threat from invasive species in the future, and alter natural disturbances, including fire (IPBES 2023).

# 1.4    Managing the threat

Weed management is based on the principles of prevention, eradication, containment and asset protection (Figure 1). Preventing invasive plant species from ever establishing is the most cost-effective form of weed management. Where infestations are small or newly established, the goal should be control with the aim to eradicate. Within core or large infestations, management should focus on avoiding spread and identifying and protecting priority assets.

Weed containment is broadly defined as actions taken to stop the spread of a weed beyond the boundary (containment lines) of a known existing infestation(s) (AWC 2012). Containment is not possible for these invasive grass species due to the number of spread pathways they have. For example, gamba grass disperses up to 100 m by wind, water and wild animals, and many kilometres with the assistance of people. See sections 2.1.3, 3.2.3 and 3.3.3 within the Background Document for more information on invasive grass spread.

**Figure 1 The generalised invasion curve showing the 4 stages of weed management.**

Modified from Victorian Government (2010) Invasive Plants and Animals Policy Framework, DPI Victoria, Melbourne.
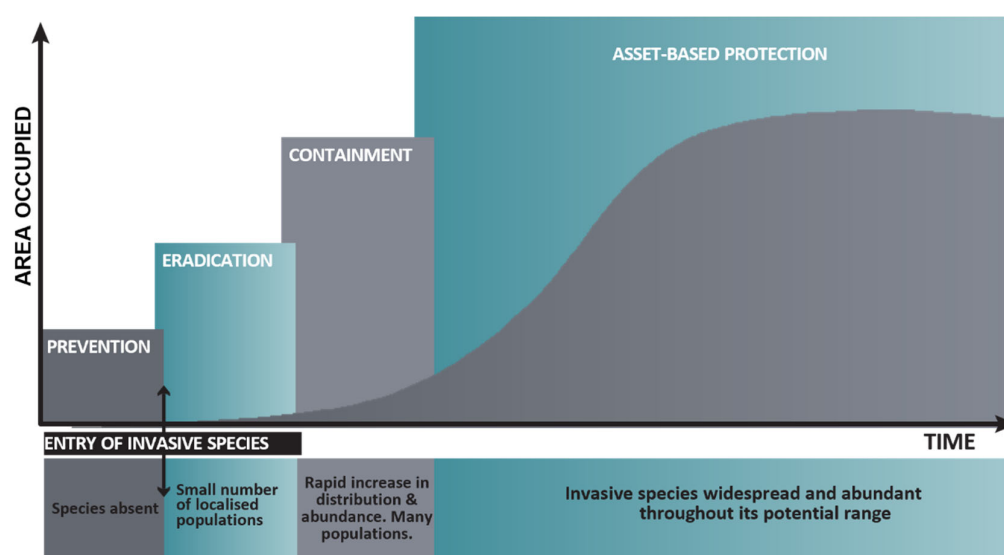


Introduced plants that provide benefit to agriculture but are highly invasive and impact conservation values are referred to as conflict species (Invasive Plants and Animals Committee 2016) or trade-off species (Godfrey et al. 2017). Gamba grass, para grass and hymenachne are all conflict species, whereas the mission grasses are not, as they are not valued by the pastoral industry. The net benefits of gamba grass to agriculture under an optimal production scenario was estimated to be $6.7 million in 2010 (Ferdinands et al. 2010; Setterfield et al. 2018). The net public cost of managing gamba grass in 2010 was estimated to be $6.05 million. When conditions are not suitable for optimal agricultural production, the cost of managing gamba grass is estimated to be greater than the net agricultural

benefit. Gamba grass has expanded its range since 2010, and some properties in the Northern Territory have relinquished their permits to grow gamba grass, such that management costs could now far outweigh the agricultural benefit.

Para grass and hymenachne were introduced for use in ponded pasture systems. Ponded pastures are created by building low walls or banks to trap water from run-off, or by diverting water courses. Such systems are usually constructed in coastal areas, or near floodplains or creeks. Para grass was introduced into Australia in the 1880s. While it is not known when it first escaped cultivation from ponded pasture, there are natural wetlands that have been invaded for around 50 years. In contrast, hymenachne is still considered to be in the early stages of invasion. It was introduced to Australia in the 1970s, and not approved for commercial release until 1988. Nutrient run-off from agriculture and alteration of natural water flow, such as through bund walls, assists the establishment of hymenachne and para grass (Adame et al. 2019).

The limited distribution data available, combined with observations from people managing these grasses, indicates these 5 invasive grass species have all increased their distribution since the last plan was released in 2012. In many locations, these grasses have also increased in density. All these grasses only occupy part of their modelled potential distribution in Australia (Duursma et al. 2013, Setterfield et al. 2018, Wearne et al. 2013). Gamba grass can spread at explosive rates (Petty et al. 2012), and in one protected area alone, gamba grass spread by 9,463 ha between 2014 and 2021 (Rossiter-Rachor et al. 2023). There is very little information on the change in the distribution or density of the mission grasses over time.

Hymenachne and para grass have both spread further south within NSW since 2012 (NSW NPWS pers. comm. 2022 29 June). This includes hymenachne spreading into what had been identified as a spread prevention zone (Grice et al. 2011), with this being the furthest south hymenachne has invaded worldwide (Jacono 2014). Hymenachne spread from 1,000 ha to 11,000 ha between 2000 and 2011 (AWC 2012). The current area infested is not known. There is some thought that para grass may have spread over much of its potential range, and could now become more abundant or denser within tropical wetlands (Hannan-Jones and Csurhes 2012, Queensland Parks and Wildlife Service 2022 pers. comm. 9 February). Detailed monitoring for parts of Kakadu National Park, demonstrates that para grass is continuing to expand in distribution and density on the freshwater floodplains (Boyden et al. 2019).

## 1.5    Review of the 2012 threat abatement plan

The 2021 review of the 2012 *Threat abatement plan to reduce the impacts on northern Australia's biodiversity by the five listed grasses* (2012 TAP), indicated that successful control of these grasses requires a concerted effort across all levels of government, ongoing funding, continuity of staff and motivated volunteers and land managers. Several actions outlined in the 2012 TAP have been achieved, and there has been considerable progress in the coordinated management of gamba grass in the NT. However, many of the issues identified in the 2012 TAP were still considered as valid.

The review concluded that current efforts are not adequate in controlling the spread of these invasive grasses, nor are they abating the threat they pose to northern Australia's biodiversity. General stakeholder feedback was that there is not enough investment and 'boots-on-the-ground'

resources available to conduct the intensive actions that are needed to control the grasses. It was also concluded that a wider, landscape-scale approach to invasive grass management is needed, rather than the existing model of individual ad hoc projects at varying scales.

The review recommended that the KTP be expanded to include Aleman grass (*Echinochloa polystachya*), thatch grass (*Hyparrhenia rufa* subsp*. rufa*) and grader grass (*Themeda quadrivalvis*), with many stakeholders concerned about the impact and spread of these introduced grass species. However, there are currently no provisions in the EPBC Act for changing the scope of a listed KTP.

Many of the actions outlined for gamba grass and the mission grasses are applicable to thatch and grader grass. Similar to gamba grass, thatch and grader grass invasion increases fuel loads and can change fire regimes. Both species increase in abundance in response to fire (Vogler 2017). Thatch and grader grass were initially thought to be weeds of roadsides and disturbed sites, but they have invaded and dominated native pastures, grasslands, and woodlands (NT Government 2013; Vogler and Owen 2008).

Similarly, many of the actions in this plan for hymenachne and para grass, are applicable to Aleman grass, and reference is made to Aleman grass in several places within the plan. Aleman grass is also an aquatic or semi-aquatic grass that was introduced for ponded pasture systems. It now invades waterways, floodplains and swamps in Queensland, Western Australia and the Northern Territory. Aleman grass can grow in deep open water, while hymenachne and para grass generally cannot.

## 1.6    Related plans and strategies

This plan encompasses principles, goals and priorities across 3 of the 4 stages of weed management as outlined in the *Australian Weeds Strategy 2017-2027*: prevention; eradication and asset protection. This plan does not focus on containment, as containment is very challenging for these invasive grass species. All these species can be dispersed by animals, and the savanna species can spread via wind, and the semi-aquatic species can be spread by water. The Australian Weeds Strategy provides national guidance on best practice weed management, with a vision of protecting Australia's economic, environmental and social assets from the impacts of weeds. The strategy aims to guide coordination of effort across all jurisdictions and affected stakeholders and to inform plans and actions. The Australian Weeds Strategy has 3 goals, with Goal 1 focusing on prevention. Prevention, detection and monitoring are important for gamba grass and hymenachne within Western Australia, and for areas of the Northern Territory, Queensland and NSW that have climatically suitable habitat for one or more species (see habitat suitability maps in Chapter 2 and 3 of the Background Document) but are currently uninvaded. Goals 2 and 3 focus on minimising impact and enhancing management, and these goals relate to all 5 invasive grass species in this plan. The goals and actions of the Australian Weeds Strategy are as follows:

Goal 1. Prevention, detection and early intervention:
    1.1 commit to and continuously strengthen effective risk-based approaches to pre-border and border activities.
    1.2 adopt consistent risk assessment and prioritisation approaches within Australia.
    1.3 develop and implement early detection, diagnostics and monitoring systems for priority weed species.

Goal 2. Minimise the impact of established weeds:

> 2.1 develop and improve national approaches to coordinate, invest and manage the impacts of weeds on values and assets.
>
> 2.2 increase participation in coordinated management approaches across all land tenures.
>
> 2.3 improve national approach, capacity and commitment to weed containment.
>
> 2.4 enhance weed control techniques and integrate management options.

Goal 3. Enhance Australia's capacity and commitment to weed management:

> 3.1 develop the knowledge, capacity and commitment of key stakeholders to play an active and constructive role in weed management.
>
> 3.2 maintain and enhance long-term research, development and extension capacity and capability.
>
> 3.3 develop and apply national data, information and knowledge infrastructure to support effective weed management.
>
> 3.4 improve institutional arrangements and decision support resources to increase the effectiveness of weed management.

This threat abatement plan aligns with the Threatened Species Action Plan 2022-2032 (DCCEEW 2022), which takes an action-based approach to protecting and recovering threatened plants and animals and priority places. Gamba grass is the focus of target 10: reduce gamba grass to an area less than its 2022 range. This plan supports the actions outlined for this target, which are to be completed by 2027:

- Develop a best practice management manual for the control of gamba grass and promote to land managers and governments.
- Promote best practice control activities to tackle the threat of gamba grass and other invasive grasses in priority places.
- Support Aboriginal and Torres Strait Islander peoples and the community to take action to manage invasive grasses, through programs including Indigenous Protected Areas.
- Work with Western Australia to eradicate gamba grass from the known location/s within the state.
- Eradicate gamba grass from Kakadu National Park.

Priority places within the action plan that are applicable to this plan are Kakadu, West Arnhem and the eastern forests of far north Queensland.

Numerous actions within the Kakadu National Park Management Plan 2016-2026 align with the objectives and actions of this plan. Relevant actions of the Kakadu National Park Management Plan have been summarised in Appendix B. Other planning documents consulted during the development of this plan include the Queensland Invasive Plants and Animals Strategy 2019-2024, Invasive Species Plan for Western Australia 2015-2019, the Environmental Weed Strategy for Western Australia and regional weed strategies. Recovery plans and conservation advices for species threatened by these grasses may also outline priorities for invasive grass management, and reference to conservation advices is included within Appendix A (Table A1).

This plan supports the objectives of the Northern Territory Government's Weed Management Plan for Gamba Grass 2020 – 2030. The principles of the Weed Management Plan for Gamba Grass could

be extended to other areas that are suitable habitat for gamba, as it takes a zoned approach to gamba management, has clear goals, performance measures for reporting and it articulates who is responsible for each action.

The Australian and Queensland Governments released the [Reef 2050 Wetlands Strategy](#) in 2024, which outlines plans for wetland science, planning, coordination and management in Reef catchments. The 5 key steps to protect wetlands in Queensland are also applicable to the long-term management of wetlands invaded by hymenachne and/or para grass. These steps are:

- Improving wetlands information for decision making and action
- Wetland planning
- On-ground activities to protect, manage, rehabilitate, and restore wetlands
- Engagement, education, communication and capacity building
- Monitoring, evaluation, reporting and improvement.

This plan will help Australia achieve target 6 of the UN Convention on Biological Diversity [Kunming-Montreal Global Biodiversity Framework](#). This target aims to eliminate or minimise the impacts of invasive alien species on biodiversity and ecosystem services by identifying and managing introduction pathways, reducing the rates of introduction and establishment of known invasive alien species by at least 50%, by 2030, eradicating or controlling invasive alien species especially in priority sites, such as islands. Australia's updated National Biodiversity Strategy and Action plan ([Australia's Strategy for Nature 2024-2030](#)) brings together existing work across the country and guides the development of new and innovative approaches to implementing the Global Biodiversity Framework.

# 2 Objectives and actions

The main goal of this plan is to improve protection for EPBC Act listed species and ecological communities threatened by gamba grass, para grass, hymenachne, mission grass, and annual mission grass. This plan also aims to protect the value of Ramsar wetlands, World Heritage properties and natural heritage places where these invasive grasses have invaded. The plan aims to:

- improve the population trajectory and extent of occurrence of threatened species impacted by these grasses

- improve the condition of ecological communities and wetlands impacted by these grasses

- prevent further species and ecological communities from becoming threatened

- reduce the threats to culture and culturally important species

- improve the health of ecosystems and Country.

This plan contains 7 objectives and outlines new and continuing actions needed to abate the threats posed by these invasive grasses:

1. Prioritise biodiversity and cultural assets and areas for protection, and increase our understanding of the ecological impacts of these grasses

2. Manage existing invasive grass infestations

3. Improve coordination of invasive grass management

4. Prevent further human assisted spread of invasive grasses

5. Map, monitor and report invasive grasses

6. Increase awareness about invasive grass impacts and best practice management

7. Improve invasive grass management through the development of new tools and understanding interactions that facilitate invasion.

These actions are based on the review of the 2012 TAP, a literature review, and an engagement process with stakeholders and experts. This plan has been developed to address the threat from the 5 invasive species within the KTP, however the concepts and approaches can be applied to other localities and invasive grass species. In particular, the plan acknowledges that some of these invasive grass species have spread southward and threaten areas in southeastern Queensland and northern NSW.

Most of the actions within this plan apply to all 5 grass species, whereas some actions are specific to the terrestrial savanna species (gamba grass, annual mission grass and perennial mission grass) or to the semi-aquatic species (para grass and hymenachne). There are specific actions that are more applicable to one state or territory. This has to do with differences in the legislation, policy, progress of actions and/or current knowledge of that species within a particular jurisdiction. Each action is

either high, medium or low priority and has a timeframe of short-term (within 3 years), medium-term (within 3 - 5 years), long-term (taking 5 years or longer) or ongoing (a continued need to undertake the action).

The threat abatement planning process included valuable assistance from state and territory governments, natural resource management agencies, scientific experts, primary industry representatives, First Nations people, not-for-profit conservation organisations and other stakeholders. We thank everyone who provided input to the plan. To progress actions under this plan, the Australian Government will rely on working in partnership with a wide range of stakeholders.

# Objective 1: Prioritise biodiversity and cultural assets and areas for protection, and increase our understanding of the ecological impacts of these grasses

**Prioritisation**

Prioritising the location of management actions is required to protect high-value conservation areas and the habitat of threatened species, and this should be an ongoing priority. Appendix A identifies EPBC Act-listed species and ecological communities which are threatened by these invasive grasses, either directly, or indirectly through changes in fire regimes (Tables A1 and A2). The protection of these species and ecological communities should be the initial priority for invasive grass management. Once the output from actions 1.1, 1.2 and 1.3 are obtained, the species in need of protection from these invasive grasses can be reassessed.

Ramsar wetlands (listed under the Convention on Wetlands of International Importance), World Heritage properties and national heritage places where these invasive grasses are present are identified in Appendix A (Table A2). Monitoring and management of invasive grasses in these areas is a high priority, with the Australian Government also having international and national obligations to ensure that the values of these sites are protected.

In order to prioritise ecological assets for protection and threat abatement, we need to know where these assets are. Having up to date maps of ecosystems or vegetation communities at appropriate scales would greatly assist with this. Standardised vegetation mapping in the NT is currently at the 1:1 million scale. There are some smaller areas mapped at high resolution, but it has been recognised that finer scale mapping of vegetation communities in NT is required for regional or catchment level planning issues (Brocklehurst et al. 2008). There is a similar issue in WA, where state-wide vegetation mapping is at a 1:3 million scale. Finer scale mapping (1:5000–1:100,000) is only available for some vegetation communities in some regions. In comparison, regional ecosystems mapping has been completed for most of Queensland at a scale of 1:100,000. Some areas in Queensland have also been mapped at a finer scale of 1:25,000 or 1:50,000, including the Wet Tropics bioregions.

Protected area management plans can provide guidance about assets which should be prioritised within those areas. For protected areas that do not have a management plan, or prioritisation process in place, the 6 prioritisation principles outlined in the Threatened Species Action Plan, can be used to help guide prioritisation of locations for invasive grass management. The prioritisation principals focus on:

- Risk of extinction – prioritising species and places under severe and imminent threat
- Multiple benefits – prioritising species and places where recovery action will benefit other species
- Feasibility and effectiveness - prioritising species and places where action can make a difference and is cost-effective
- Importance to people - prioritising species and places of cultural significance
- Uniqueness - prioritising species and places that are unlike any other
- Representativeness – achieving balance in selected species and places.

All 5 species of invasive grass covered in this plan are present within Kakadu National Park, and one or more of these invasive grass species are present within numerous conservation areas in WA, NT and Queensland, including high conservation value wetlands. Previous modelling indicated that para grass was occupying 2% of the optimal habitat that existed within the Magela Creek floodplain within Kakadu National Park, with 30% of the floodplain calculated to be optimal habitat (Boyden et al. 2018). Managing para grass and hymenachne within the floodplains of Kakadu National Park is already a priority for the park (see Appendix B) and should continue to be so. A large proportion of Kakadu National Park is also highly suitable habitat for gamba grass, in particular the drainage lines within the lowland woodlands and the margins of the floodplains. A plan commenced in 2023 to eradicate gamba grass from Kakadu National Park.

**Ecological impacts**

There is limited information about which native species are threatened by hymenachne and para grass, with 10 and 11 species respectively known to be threatened (see Appendix A, Table A1). Few northern Australia freshwater species are listed as threatened under the EPBC Act, and it is thought that freshwater species are underrepresented on national and state threatened species lists (Lintermans et al. 2020). There is often a lack of data on freshwater taxa, with freshwater flora and fauna generally receiving less attention and conservation effort than terrestrial and marine species (Birnie-Gauvin et al. 2023; Januchowski-Hartley et al. 2011).

Most of the Indigenous land managers consulted during developing of this plan reported that cultural values were being threatened by one or more of these invasive grasses (see section 5 within the Background Document). The aspects of culture reported to be impacted were wide ranging including physical access to country and resources (bush tucker, medicine, water, hunting), and damage to sacred sites, especially from inappropriate fire management. Hymenachne and para grass are restricting access for species traditionally found on Country, including preventing barramundi migrating from the floodplains after their breeding season. One ranger stated "olive hymenachne altered native feed for animals, potential to change water flow, choke up billabongs and habitat alterations".

The Indigenous land management groups consulted, were also aware of the impacts of gamba grass and the mission grasses on biodiversity assets. There is considerable alignment across cultural and biodiversity values, and invasive grass management programs can be strategically developed and implemented to maximise protection of these values. When Indigenous land management groups have more items in their work plan than resources to perform them, invasive grass management programs that address conservation of both biodiversity and culture could be a higher priority.

**Table 2 Actions for objective 1, prioritise biodiversity and cultural assets and areas for protection, and increase our understanding of the ecological impacts of these grasses.**

| Action | Priority and timeframe | Output and outcome |
|---|---|---|
| **1.1 Identify biodiversity assets for protection**<br>Identify key biodiversity assets, including islands, for priority protection from invasive grasses.<br>Undertake an expert elicitation process to review and update the list of EPBC Act listed species, and ecological communities, Ramsar wetlands and heritage places impacted by these invasive grasses. Determine how the invasive grasses are impacting biodiversity assets (e.g. changes in fire regimes, competition, change in vegetation structure, nutrient cycling).<br>Identify if evidence of impact is required for any species, ecological communities and wetlands. | High priority<br>Short term | Database of native species and ecological communities impacted by invasive grasses updated and made accessible to the public. Stakeholders have a clear understanding about which species and ecological communities each invasive grass threatens.<br>Identification of priority assets will allow management resources to be strategically focused to gain maximum benefit.<br>Gaps in knowledge identified in the process will feed into research conducted in Action 1.3. |
| **1.2 Identify Country for protection**<br>Identify the location of biodiversity assets and priority Indigenous cultural values that are at risk of invasion by invasive grasses. Identify strategic protection locations and activities. | High priority<br>Medium to long term<br>(depending upon invasive grass species present) | Location of biodiversity assets and priority cultural values identified. First Nations people engaged and consulted to see where invasive grass management can be undertaken for landscape protection of country for biodiversity and cultural outcomes.<br>Species and communities most at risk identified, so that managers are able to prioritise areas at high risk of grass invasion. Outputs fed into Objective 2.<br>Grass invasion into priority areas prevented, with prevention more viable and cost effective than management once a weed is established. |
| **1.3 Produce vegetation maps at appropriate scale to aid prioritisation of ecological assets for threat protection**<br>Produce finer scale standardised vegetation (regional ecosystem mapping) for regions of the NT and WA where mapping is currently at 1:1 million scale or greater. | High priority<br>Medium term | Jurisdiction wide standardised vegetation mapping at a suitable scale (e.g. 1:100,000) for all the NT and WA.<br>Improved information for regional and catchment level planning, and prioritisation of assets for protection. Improved threat abatement and spread prevention for susceptible vegetation communities. |
| **1.4 Identify threat mechanisms**<br>Determine if the species, ecological communities and heritage places and wetlands identified in Action 1.1 as lacking evidence, are threatened by one or more invasive grass species and determine the mode of threat. | Medium priority<br>Medium term | Improved understanding of what species, ecological communities, heritage places and wetlands are threatened by grasses, and how the invasive grass specie(s) directly or indirectly threatens. This information will be used to prioritise management (Objective 2) and in communication material (Objective 6). |
| **1.5 Ecological impacts of the mission grasses**<br>Determine the ecological impacts of perennial mission grass and annual mission grass. Apart from their impacts on fire, little information is known about what species and ecological communities these grasses threaten and if these 2 species threaten similar species. | Medium priority<br>Short term | Improved understanding of the impacts of perennial and annual mission grass on threatened species.<br>Information on the ecological impacts will be used to prioritise areas for monitoring (Objective 5), control and eradication (Objective 2). This information will also be used in communication and education material to explain why these grasses should be managed (Objective 6). |
| **1.6 Ecological impacts of hymenachne hybrid**<br>Undertake research to obtain a better understanding of the biology of *Hymenachne* x *calamitosa*, including its habitat preferences, reproduction and ecological impacts. This includes understanding the frequency of hybridisation with *Hymenachne acutigluma.* | Low priority<br>Short term | Improved understanding if the hybrid is as important to control as *Hymenachne amplexicaulis.* This will assist in prioritising areas for control and eradication (Objective 4). An improved understanding if hybridisation occurs readily, and if it occurs across all of the distribution where *Hymenachne amplexicaulis* and *Hymenachne acutigluma* both occur. |

| Action | Priority and timeframe | Output and outcome |
|---|---|---|
| **1.7 Environmental cost of inaction**<br>Undertake modelling to determine the environmental cost of these invasive grasses if current control efforts are not improved. | Medium priority<br>Short term | An understanding how many species and ecological communities are at risk of becoming threatened or extinct if invasive grass management efforts are not increased. This information can be used to promote the need for invasive grass management (Objective 2), monitoring (Objective 5) and prioritising management (Objective 1), |

# Objective 2: Effectively manage existing invasive grass infestations

Ongoing effective management of existing invasive grass infestations is a high priority, and is required to ensure the long term survival of threatened species and ecological communities threatened by these grasses, and the protection of heritage places and Ramsar wetlands invaded by these grasses.

Effective invasive grass management requires good planning and coordination (Objective 3), combined with mapping and monitoring (Objective 5). A range of tools are available to manage existing invasive grass infestations. The Background Document includes an overview of the current management techniques for gamba grass (see section 2.1.6), the mission grasses (section 2.2.4), hymenachne (section 3.2.5), and para grass (section 3.3.5). Since the 2012 threat abatement plan, there has been increased understanding of how to effectively manage gamba grass.

These grasses occur across a range of land tenures and jurisdictional boundaries. A cross-tenure, landscape-scale approach will be required for successful protection of many biodiversity and cultural assets. The Australian Government can provide leadership to enable engagement and cooperation between government, industry and the community. Many Indigenous Protected Areas (IPAs) in northern Australia are likely to have invasive grasses present, or are at risk of being invaded by one or more species of invasive grass. Therefore, it is important Land Councils, Indigenous Rangers groups and other First Nations people are engaged in invasive grass management programs, and that the objectives of the control program match the outcomes important to each group or organisation. Management for healthy Country and cultural priorities can have positive biodiversity outcomes on a landscape scale.

Annual and perennial mission grasses are no longer promoted for agricultural use and have little to no commercial feed value for livestock (Qld Department of Agriculture and Fisheries 2022 pers. comm. 2 June). Stakeholders reported that mission grass is rapidly spreading in parts of Queensland. It has been widespread in the Darwin area for over 40 years, with controlled areas requiring frequent treatment due to re-invasion (Kean and Price 2002). Mission grass is also known to invade areas after local eradication of gamba grass (NT Government 2010). However, gamba grass and perennial mission grass have a short-lived seed bank (1 to 2.5 years), making localised eradication possible when there is active management for at least 3 years followed by monitoring. It would be beneficial if gamba grass and the mission grasses were controlled at the same time where they co-occur. However, with the mission grasses having a greater distribution and perceived lower threat than gamba grass, this will present a challenge to implement.

There is one known gamba grass infestation in WA, and this is part of an active eradication program. Control has been successful as there has been good year-round access to the plants (WA Department of Biodiversity Conservation and Attractions pers. comm. 2022 19 September).

Containment and control of invasive species in connected water systems has generally been ineffective (IPBES 2023). The management of hymenachne invasions in conservation areas is complex and expensive (Wearne et al. 2011), with 10 to 20 years of active interventions and monitoring typically required (Cattarino et al. 2018). The situation is similar for para grass. This is because

hymenachne and para grass can reproduce from small vegetation fragments, and hymenachne seeds can survive for more than 8 years. It is not known how long the soil seed bank of para grass remains viable, with some reports of para grass having non-viable seeds and a very small seed bank (Wearne et al. 2011), with others reporting seeds lasting decades (Stone 2010). For para grass and hymenachne, local eradication is possible in waterways where these grasses are not present higher within the catchment. Monitoring uninvaded catchments, early detection and treatment of new incursions, and preventing further spread is a high priority.

There is a single known infestation of hymenachne in the East Kimberly region of Western Australia. This was discovered in 2017 and is on track to being eradicated, with no new plants detected since 2019. Unlike the infestations in the Northern Territory, there were no crocodiles present, enabling people to safely get in the water to physically remove vegetation fragments and prevent reinvasion (WA Department of Biodiversity Conservation and Attractions (DBCA) pers. comm. 2022 19 September).

Hymenachne is now present in northern NSW, with small, isolated infestations in the Richmond, Tweed and Clarence River catchments. All known infestations are currently subject to control programs, with the aim of eradication. The spread of hymenachne within NSW appears limited by the cooler weather and frosts, however in Australia, hymenachne is now growing beyond the climatic range of the native distribution in South America (Wearne et al. 2013). There are para grass infestations in northern NSW near priority conservation sites. The para grass is being controlled, but eradication is currently not being attempted.

**Table 3 Actions for objective 2, effectively manage existing invasive grass infestations**

| Action | Priority and timeframe | Output and outcome |
|---|---|---|
| **2.1 Prevent further spread of invasive grasses**<br>Eradicate all new incursions as they are detected (outputs from actions 2.1, 5.2, and 5.5) and contain existing infestations so that there is no increase in the abundance and spatial extent of these grasses. | High priority<br>Long term | Stabilised or reduced distribution and abundance of invasive grasses. New isolated outbreaks detected and immediately controlled. Relevant state and territories have adopted legislation, policies and/or programs to eradicate isolated infestations and to contain other infestations.<br><br>Early detection and local eradication of new incursions will prevent the establishment of a seed bank reducing chance of weed emergence after treatment of adult plants. |

| Action | Priority and timeframe | Output and outcome |
|---|---|---|
| **2.2 Invasive grass management priorities**<br><br>Target invasive grass management to species, ecological communities, heritage places and Ramsar wetlands identified in Appendix A (Tables A1 and A2), and to those identified from outputs from actions 1.1, 1.2, 1.3, 1.5 and 1.6. | High priority<br><br>Long term | Grass management implemented based on prioritisations and information obtained via other actions. Grass cover and density in and around priority sites/species habitats reduced and lower densities maintained.<br><br>Invasive grass eradication commenced on high conservation value islands where feasible.<br><br>Increase in land area where invasive grasses are effectively managed for biodiversity outcomes. Key assets protected from invasive grasses.<br><br>Increased population and/or ecological condition of species/communities where invasive grass threats have been reduced. |
| **2.3 Reduce the incidence and extent of these invasive grasses that threaten cultural significant areas as identified in Action 1.2**<br><br>Eradicate gamba grass infestations within Kakadu National Park and control hymenachne, para grass, and the mission grasses within Kakadu NP. | High priority<br><br>Long term | Targeted invasive grass management undertaken to limit the impacts on key areas, assets and/or values.<br><br>Invasive grass eradication undertaken around significant cultural sites and waterways. |
| **2.4 Control gamba and mission grasses at the same time at high priority sites**<br><br>Encourage the control of annual mission grass, perennial mission grass and gamba grass at the same time where they co-occur using best practice management. This is a priority at: 1. sites that have been invaded for a long time (>25 years) and have reduced native vegetation seedbank; and, 2. high value sites where gamba grass and mission grass threatens species and/or cultural heritage. | Medium Priority<br><br>Ongoing | Mission grasses controlled at the same time as gamba grass where they co-occur. Adoption of gamba grass best practice management guide.<br><br>Reduce the probability of mission grass invading where gamba grass has been controlled.<br><br>Improved longer term outcomes for removing invasive grasses from the landscape. |
| **2.5 Control hymenachne and para grass at the same time**<br><br>Promote the control of both hymenachne and para grass at the same time where they both occur within a waterway or floodplain.<br><br>Consideration should also be given to controlling other invasive aquatic weeds present within significant environmental and cultural waterways at the same time (e.g. Aleman grass*)* | Medium priority<br><br>Ongoing | Hymenachne, para grass and Aleman grass all controlled at the same type where they co-occur.<br><br>Reduced probability of hymenachne invading where para grass has been controlled, and vice versa.<br><br>Similarly, reduce the probability of Aleman grass (highly saline tolerant) invading where para grass and hymenachne have been controlled.<br><br>Improved longer term outcomes for floodplains and waterway. |
| **2.6 Priority areas for hymenachne management**<br><br>Output from Action 5.1 on habitat suitability and current status of hymenachne in risk catchments used to inform priority areas for hymenachne management. | Medium priority<br><br>Medium term | Priority areas for hymenachne management known. Hymenachne management undertaken in priority areas, leading to a reduction in hymenachne cover and extent. |
| **2.7 Cross tenure invasive grass management**<br><br>Provide incentives to landholders to participate in coordinated cross tenure invasive grass management programs. This could include training, access to equipment, plant identification services or a herbicide rebate after grass control. In return, landholders would be encouraged to report what species of grass they controlled and the outcomes of the control work. | Medium priority<br><br>Ongoing | Incentive programs for participation in invasive grass management continued or designed and commenced.<br><br>More coordinated landscape control of invasive grasses enabled.<br><br>Reduced probability of invasive grasses reinvading high conservation value areas where control has taken place. |

| Action | Priority and timeframe | Output and outcome |
|---|---|---|
| **2.8 Engagement in training activities** <br><br> Invite Indigenous rangers to particulate in invasive grass control programs and best practice management field trials, with a focus on learnings that can be transferred to management of invasive grasses to achieve the outcomes that a group or IPA would like to achieve (e.g. access to Country, improved habitat for a totem species, reduced fire risk). | High priority <br><br> Ongoing | This action also links with Action 2.7, and contributes to cross tenure invasive grass management. <br><br> First Nations people and Indigenous rangers invited and participated in invasive grass control and demonstration of best practice management. First Nations land managers have increased skills, and increased confidence to manage these grasses for their communities desired outcomes. |
| **2.9 Invasive grass management costs** <br><br> Develop economic models of the cost of controlling, and locally eradicating these grasses (where feasible). There are some cost estimates for gamba grass and para grass control in the NT, but no recent estimates for the other species or jurisdictions. This modelling can link to the cost of inaction in terms of impacts on threatened species (Action 1.7) and include cost of management in the future if control efforts are not increased now. | Medium priority <br><br> Short term | Economic model(s) developed that outline the cost of a) controlling and b) eradicating these grasses. <br><br> Increased understanding of the level of resources required to effectively manage these grasses, and how the cost of management will change in the future if increased action is not taken now. The cost of lack of action on management costs and threatened species (Action 1.7) is a powerful tool for conveying why action should be taken now and can be used in communication material (Objective 6) and policy documents. |
| **2.10 Fire exclusion** <br><br> Trial the exclusion of fire as management tool for managing gamba grass in conservation areas at a range of sites and vegetation communities using the methodology developed by Rossiter-Rachor and Setterfield (2019). <br><br> Investigate if a similar fire exclusion and herbicide use approach could also be used as a tool to better manage mission grass invasions in conservation areas. | High priority <br><br> Long term (minimum 5 years) | Trails established at sites invaded by gamba and/or mission grasses. <br><br> Fire exclusion as part of an integrated management approach is currently controversial in many parts of northern Australia. Communication of output from successful trials could lead to increased uptake of a methodology that has positive ecological outcomes. |
| **2.11 Effective management of invasive grasses within existing pasture** <br><br> State and territories with existing invasive grass plantings that are actively managed for livestock production to be subjected to provisions for dealing with ineffective management and changing land use and ownership. | Medium priority <br><br> Medium term | Policy and procedures in place to address ineffective management of gamba grass, para grass and hymenachne across northern Australia. There are already policies in place in the NT for gamba grass pasture within the gamba grass declaration zones (management zone and an eradication zone). <br><br> This will help reduce the spread of these grasses, but it should be noted that these grasses cannot be effectively contained within a managed grazing system. |
| **2.12 Link to threatened species and other plans** <br><br> Ensure that management plans addressing these invasive grasses in high-priority areas include recognition of the ecological or cultural asset(s) that are threatened or need protection and/or monitoring. Priority areas are to be determined by actions 1.1, 1.5 and 1.6. Ensure that weed strategies/plans, cross reference conservation planning documents and the threat abatement plan. | High priority <br><br> Ongoing | Management plans addressing invasive grasses are linked to threatened species recovery plans and conservation advices for areas where these species are thought to occur. This will help to maintain awareness of any listed species or ecological communities potentially affected by management actions. Contractors have increased awareness of what needs protecting, or why the work is being carried out (e.g. reduce a threat). <br><br> In the long term this should lead to improved outcome for threatened species. |

# Objective 3: Improve coordination of invasive grass management

For the on-ground management of these invasive grasses outlined in Objective 2 to be effective, it needs to be conducted in a planned and coordinated manner and be accompanied by monitoring and mapping (Objective 5). Coordination of management activities is particularly important given these invasive grasses occur across a range of habitat types, land tenures and jurisdictions, and control requires sustained effort.

Collective action and collaboration among agencies, organisations and landowners is one of keys to successful management of invasive species (Graham et al. 2019). This can include stakeholders participating in the planning process and developing shared goals (Abeysinghe et al. 2023). An array of stakeholders requested improved coordination and guidance for invasive grass management in northern Australia, particularly in north Queensland. Some Queensland stakeholders requested a model similar to what is used for gamba grass within the Northern Territory, which includes a clear management plan accompanied by guidance from a weed advisory committee.

This plan supports the development of a series of regional invasive grass management strategies. These strategies will help frame the objectives and actions of this national threat abatement plan at a finer scale, which is required to guide on ground action. Each strategy would be developed in consultation with stakeholders, and outline the aims, actions, monitoring, and the responsibilities of all people, land managers and organisations within a discrete region. The addition of regional level maps to visualise agreed zones for surveillance, spread prevention, control and eradication would help communicate aims and activities. Each strategy could cover all 5 invasive grasses, or focus on just the savanna grasses (gamba grass, annual and perennial mission grass) or the aquatic grasses (hymenachne and para grass), depending upon their presence, level of threat, and stakeholder interest.

Gamba grass and hymenachne each had a Weeds of National Significance Coordinator appointed soon after they were declared Weeds of National Significance. These coordinator positions assisted in communicating the impact of these grasses and the need for improved management. These coordinator positions ended in 2013. Having national coordination, though a dedicated coordinator or an alternative mechanism, would allow the important work of these WoNS coordinators to continue and improve implementation of this threat abatement plan. National coordination could encourage and empower groups to work together towards regional scale control, assist with the organisation of extension activities focused on best practice management options, assist with raising awareness (Objective 6) and roll-out findings and communication products as they become available.

First Nations people are responsible for managing large areas of northern Australia. This includes pastoral leases, Indigenous Protected Areas and jointly managed national parks. Indigenous rangers play a key role in protecting biodiversity from the threat of invasive grasses and are vital in locating and managing satellite infestations. During consultation for this plan ranger groups emphasised the importance of information exchange and being shown firsthand what is happening in the landscape with invasive grasses. There was strong support for having coordination across ranger groups.

**Table 4 Actions for objective 3, improve coordination of invasive grass management.**

| Action | Priority and timeframe | Output and outcome |
|---|---|---|
| **3.1 Invasive grass national coordination**<br>Establish mechanisms to promote coordination and collaboration across stakeholders in northern Australia invasive grass threat abatement. | High priority<br>Ongoing | An effective national coordination mechanism established and maintained.<br>Effective engagement with a broad range of stakeholders on invasive grasses in northern Australia. Increased awareness of the need to effectively manage the 5 invasive grass species in a timely manner.<br>Increased dissemination of information, and the coordinator seen as a point of contact for reliable information and connection to other assistance.<br>Improved implementation of the threat abatement plan, ultimately leading to reduced invasive grass spread and area infested. |
| **3.2 Invasive grass networks**<br>Support the development of regional invasive grass management networks for Indigenous land management groups, and create pathways for ranger groups to obtain the information and training they require for on ground management of invasive grasses. | Medium priority<br>Ongoing | Invasive grass management networks established and people voluntarily participating in them.<br>Indigenous land managers better engaged to address impacts of invasive grasses on their land. Improved information transfer and support for new staff in manager roles.<br>Indigenous land management groups have an increased role in raising awareness in their communities on the impact of invasive grasses on Country.<br>Groups working together across common boundaries to support invasive grass management in priority locations. This also links and overlaps with Action 5.7. |
| **3.3 Develop regional invasive grass strategies**<br>Develop a series of regional invasive grass management strategies for regions with existing infestations of one or more of the 5 invasive species in this plan. A priority is a strategy for north Queensland, in particular the Cape York region. The strategies could align with the NT Government Gamba Grass Weed Management Plan. | High priority<br>Short term | One or more regional invasive grass strategies developed clearly outlining aims, responsibilities of all people, land managers and organisations, actions and monitoring.<br>Improved coordination of invasive grass management, leading to landscape scale control of invasive grasses.<br>Increased understanding of everyone's roles and responsibilities in invasive grass management. |

# Objective 4: Prevent further human assisted spread of invasive grasses

The spread pathways for all 5 species of grass are well understood, with there being both natural (e.g. wind, water and wildlife) and human assisted (anthropogenic) spread pathways. Most human assisted spread is accidental, such as seeds and vegetative matter caught on vehicles, boats and machinery. Inadvertent dispersal by off-road vehicles is a spread pathway of particular concern for all species in this plan. Such activity increases the risk of new infestations forming in areas rarely visited by people, especially by those who know what these grasses look like. The deliberate planting of new pastures, and the movement of cut fodder that contains gamba grass and the mission grasses seeds are also known spread pathways.

Preventing further spread of these invasive grasses is a cost-effective form of management. Prevention can be achieved through managing anthropogenic spread pathways, state and territory border biosecurity, mapping and monitoring (Objective 5), education (Objective 6) and preventing import of additional varieties or forms of these grass species. These grasses all vary in their weed classification throughout Australia, from no declaration through to eradicate (see section 1.5 of the Background Document). This means some of these species can still be legally moved, traded, and deliberately planted. Such actions can contribute to the further spread of these invasive grasses. The principles of invasive grass spread prevention are outlined in section 3.5 of the Background Document.

There are many high quality existing publications and resources from local and state governments, natural resource management organisations and industry groups that focus on preventing the accidental spread of weeds. These should be promoted and distributed more broadly.

Stakeholders mentioned that some washdown facilities in northern Australia are on back roads and are only known by locals. Some facilities also require a token for use, which needs to be obtained from a local government office or similar. Location and method of payment could create barriers to use of such facilities by tourists and visiting contractors. Improved sign posting and promotion could assist overcome this. More washdown facilities are also required, especially near entrances to high value conservation areas. Some concern was raised by stakeholders on the cost of running such facilities and vandalisation or theft of items from such facilities.

The initial spread of hymenachne and para grass in northern Australia was predominately through deliberate planting of seeds or vegetation fragments. Para grass and hymenachne are still viewed as useful production grasses by some graziers. Cattle are reluctant to graze these grasses in water, and they are only a useful feed once the water they are growing in dries out or recedes. In Queensland, para grass and hymenachne are no longer recommended for use in ponded pasture (Queensland Government 2013), however they are both still promoted on a range of websites for agricultural use in wet and flooded soils (e.g. Cameron 2008). While there has been a decrease in the deliberate spread of these grasses, most landholders are not actively managing to keep para grass and hymenachne contained on their property (Qld Department of Agriculture and Fisheries 2022 pers. comm 27 May). Hymenachne and para grass can be dispersed by floods, highwater flows, waterbirds, boats and vehicles.

There are existing gamba grass pastures in Queensland and the NT that are still actively managed to maintain the gamba grass, with gamba grass still valued by many graziers for pasture and fodder production in Queensland and parts of the NT. In Queensland, gamba grass is also used in intensive feed lots and muster yards. Growing gamba grass as fodder increases the fire and spread risk, as it is generally grown to a high biomass before harvest. When used in a grazing system, it is meant to be intensively grazed to keep the grass below 70-90cm in height to maintain palatability. The NT Government have clear goals for eradication and control of gamba grass in different regions, as outlined in the Weed Management Plan for Gamba Grass 2020 – 2030. The approach taken with gamba grass management in the NT could be applied to far north Queensland.

**Table 5 Actions for objective 4, prevent further human assisted spread of invasive grasses.**

| Action | Priority and timeframe | Output and outcome |
|---|---|---|
| **4.1 Biosecurity and weed hygiene protocols**<br><br>Improve and promote biosecurity protocols and vehicle hygiene material for visitors, contractors and staff. Good extension material already exists and some organisations are already well versed its application, however material needs to be produced that is targeted and/or promoted to a broader audience who may not be aware of the spread pathways for these grasses (e.g. 4wd clubs, hunters, tourists, out of town contractors). | High priority<br>Short term for development, ongoing for promotion | Biosecurity and vehicle hygiene education material promoted and made readily available to a broad range of target audiences.<br><br>Increase in awareness of how an individual's actions can spread weeds. Increase in people following vehicle hygiene measures.<br><br>This action also contributes towards Objective 6. |
| **4.2 Increase awareness of biosecurity protocols among those responsible for roadside maintenance**<br><br>Increase the awareness among departments responsible for transport and roads, and contractors who do road slashing and mowing to be more aware of weed hygiene. This includes promoting the slashing and mowing of roadside vegetation when grasses are not seeding or consider the direction in which they travel if grasses are seeding (move from clean to invaded areas). | Medium priority<br>Ongoing | Relevant departments and agencies engaged on weed hygiene. Policies and practices put in place to prevent accidental weed spread along transport corridors.<br><br>Staff and contractors more aware of how their actions could spread weeds, and how to minimise weed spread.<br><br>Time of work changed to when grasses are not seeding, or work carried out from clean to weed infested areas. |
| **4.3 Prevent human assisted spread by discouraging fodder production and transportation**<br><br>Discourage fodder production using any of these grass species, especially for hay that is transported off a property. For existing fodder production, promote the harvest and bailing of invasive grasses before they set seed and before they reach a high biomass. Increase promotion and availability of existing best practice fodder production guides (e.g. Reducing weed risks from fodder). | High priority<br>Ongoing | Increase in dissemination and availability of best practice fodder production guidelines.<br><br>Reduction in the amount of gamba grass being grown for fodder production. Reduction in gamba grass fodder being transported off property. Increase in land managers harvesting gamba grass at a lower height, and therefore reducing the fire risk.<br><br>Decrease the risk of accidental spread of seed from fodder, therefore preventing new infestations. |
| **4.4 Prevent human assisted spread by discouraging new cultivation and distribution**<br><br>Discourage any new cultivation, distribution, sale or supply of these invasive grasses. Also discourage the importation of new varieties, forms and hybrids of para grass and the mission grasses into Australia.<br><br>This can be done through the creation of new policies, via education and communication programs (Objective 6) and working with horticultural companies and agricultural agencies. | High priority<br>Ongoing | Policies in place that discourage or prevent any new cultivation, distribution, sale or supply of any of these invasive grasses.<br><br>Decrease in agricultural use of these grasses, which will reduce the spread of these invasive grasses.<br><br>No importation of new varieties, forms and hybrids of para grass and the mission grasses that could potentially be as invasive as the parent material, or that can grow in different conditions (e.g. cold tolerant). |

# Objective 5: Map, monitor and report invasive grasses

Having baseline invasive grass distribution data is essential for assessing the scope of the problem, developing optimal control strategies and determining what resources are required to effectively manage the problem (Rossiter-Rachor et al. 2023). Invasive grass surveys are currently not carried out regularly or over a sufficient area, such that we do not know how fast these invasive grasses are spreading in most of northern Australia. There are extensive sparsely populated areas in northern Australia, and this increases the likelihood that an invasive grass could spread without being detected. Spread prevention and early intervention are far more effective than controlling established infestations, but there is a tendency for invasive grasses to be ignored until they can be seen to be having an impact or are an issue, with early outliers often not looked for or controlled (Qld Department of Agriculture and Fisheries 2022 pers. comm. 1 August).

Ongoing monitoring and evaluation of control activities is critical to making evidence-based decisions and improve management practices, but monitoring is currently highly variable between programs. Common metrics reported, such as volume of herbicide applied, reflect the control effort being applied and do not indicate change in the level of the threat. Invasive grass control programs need clearly defined goals and outcomes to ensure meaningful biodiversity outcomes. This includes defining outcomes both in terms of level of threat reduction, and responses in the state of biodiversity. This will enable managers to better define the activities and resources required to achieve these outcomes (Rossiter-Rachor et al. 2023).

Data on invasive species distribution, areas under management and monitoring outcomes need to be readily available to a range to stakeholders including local, state and the Australian government, NRM organisations and managers of protected areas. Having open and interoperable information systems can improve the coordination and management of invasive species across various boundaries (IPBES 2023). Various stakeholders in north Queensland have requested up to date invasive grass mapping and improved access to mapping data and maps. By making sure land managers and policy makers have access to the most current data, this can reduce duplication of effort, assist with prioritisation, early detection, and improve coordination and effectiveness of the response.

Hymenachne and para grass are far more difficult to control than gamba grass and the mission grasses, such that eradication is unlikely in the NT and Queensland (e.g. Rolfe 2007). Therefore, containment and monitoring for new incursions for these 2 species is critical. Wearne et al. (2013) identified 16 catchments that were at high risk of hymenachne invading and becoming established. These catchments are located in the Cape York region of north Queensland (Archer River, Ducie River, Jacky Jacky Creek, Jeannie River, Stewart River), southern Queensland (Noosa Rivers, Shoalwater Creeks, Water Park Creek), and the Northern Territory (Blyth River, Buckingham River, Goomadeer River, Koolatong River, Liverpool River, Moyle River, Walker River). These catchments all have high habitat suitability for hymenachne and are all connected to invaded catchments. These catchments should be a priority for finer scale habitat suitability modelling and monitoring for hymenachne.

Monitoring also needs to be carried out, or reported on, the current status of hymenachne invasion in the 24 catchments identified as high risk for spread and establishment by Wearne et al. (2013).

This is a high priority for areas with high conservation value, and/or where freshwater dependent species and ecological communities occur that could be threatened by hymenachne. These catchments are within the NT (Adelaide River, Daly River, East Alligator Creek, Finniss River, Goydor River South Alligator River) and north Queensland (Don River, Endeavour River, Holroyd River, Jardine River, Normandy River, Water Park Creek).

There are some existing detailed distribution maps available for some of these grasses (e.g. gamba grass, hymenachne and para grass), but the time series and spatial resolution varies greatly between jurisdictions, and in some cases, only small areas are mapped in detail (e.g. a catchment or national park). A national gamba grass distribution map is currently being prepared by ABARES.
An approximate distribution map for hymenachne in Queensland was produced in 2023, based on information gathered in expert elicitation workshops and surveys. It is possible to view how hymenachne invasion is thought to have changed over time, but the information in the map has not been ground truthed. There have been no broad scale monitoring or mapping of annual or perennial mission grass.

Adams et al. (2015) developed a model to help predict weed spread when mapping information is available for 2 time points, in addition to other variables. The model predicted that gamba grass in the Batchelor region of NT, and para grass extent in Kakadu National Park would double over 10 years (2015 to 2025) in the absence of management actions (Adams et al. 2015). These models could be updated, so that the future mapped distribution can be used to identify priority areas for eradication and control to reduce the predicted increase in infestation.

A methodology has also been developed to monitor gamba grass using remote sensing, by analysing purchased medium-resolution, multispectral satellite imagery (VHR WorldView-3 imagery) (Shendryk et al. 2020). This methodology needs testing in a range of landscapes and seasons, and to be simplified, if possible.

Monitoring and surveying can produce a lot of data, and it is critical that there are simple systems in place to organise, analyse and present this information. Otherwise, there is a risk the information would not be used to improve decision making. Technology, especially artificial intelligence, can play a role in automating data processing, especially from aerial surveillance imagery.

In some lines of work or locations, there can be a high turnover of staff, making it difficult to track program success or improve programs. Supporting Indigenous land management groups to monitor their invasive grass treatment efforts, securely store data and interpret the data to track their treatment efforts, will enable them to finesse their treatment programs and increase their efficiency in responding to the threat of invasive grasses.

Prior to 2023, there was no national weed identification or reporting portal for the Australian community. The WeedScan app and website were released in late 2023, and uses a CSIRO AI identification model to assist with weed identification. The initial version includes all the invasive grasses in this plan. Users are able to submit, view and share records and notify state and local government of new weed incursions. The app does not include features for mapping and monitoring weeds at a site level. This plan supports the continued development of this app for invasive grass species.

The ACT government use the NatureMapr citizen science app and Field Maps©, an ArcGIS Online mapping app to assist with environmental weed mapping and monitoring. The data from these 2 apps has recently been integrated, allowing information to be viewed on new weed incursions, weed management and significant native species. Unlike other citizen science apps, NatureMapr uses experts to confirm species identification, and new incursions can be linked to herbarium voucher specimens. Species alerts and reports can also be created. These apps have recently been taken up by some local government areas in NSW, and there is interest in expanding their use across all of Australia. Having a consistent weed mapping and reporting system across Australia would assist in reporting and for developing management programs for incursions across and near state and territory borders.

The public can also report invasive grass sightings to the iNaturalist or BioCollect website or app, but neither of these apps are specifically aimed at identifying, reporting or monitoring weeds. BioCollect, hosted by the Atlas of Living Australia, is designed for scientists, citizen scientists and natural resource managers to collect and manage ecological and natural resource management data. As weed identification, mapping and monitoring apps are released, updated or their geographic use expanded, it will be important to consider how these apps overlap and how the information they gather can be used to improve invasive species management.

There is still a gap between the possibilities, and the practical use of remote sensing technology for weed management (Müllerová et al. 2023). There has been success in the use of drones, or unstaffed aerial vehicles (UAV) for weed management in cropping areas, but further refinement and simplification is required before drones become a standard tool for use in conservation areas. Barriers to overcome include the cost, level of technical expertise required, and the large quantity of data that can be produced. Drones are also required to be operated within the visual line of sight, which can be challenging. A permit needs to be applied for, to fly beyond visual line-of-sight (BVLOS) from the Civil Aviation Safety Authority.

There has been more success in the use of drones in wetlands than woodlands, as they tend to be more open. Long range drones have been used to capture high quality spectral images to map para grass within Kakadu National Park, with around 10 km of flight path being able to be imaged per day. Drones have also been successfully trialled by Cape York NRM in partnership with Queensland Parks and Wildlife Services, to apply herbicide on hymenachne in wetlands (Cape York NRM 2022).

Manual photo processing of imagery for invasive grass monitoring is costly and time consuming. Development of algorithms for use in conjunction with image analysis software to automate the weed detection process lowers costs, and this is required for all these grasses. Parks Australia have a project underway to develop drone technology to detect and spot spray buffel grass in central Australia. Lessons from this project, once completed, could be transferred to the 5 species of invasive grass covered in this plan.

**Table 6 Actions for objectives 5, map, monitor and report invasive grasses.**

| Action | Priority and timeframe | Output and outcome |
|---|---|---|
| **5.1 Distribution of invasive grasses**<br><br>Conduct annual surveys to determine the distribution of the 5 invasive grass species. This should include monitoring the extremities of infestations, looking for new satellite infestations and monitoring key conservation assets that are currently free of invasive grasses but are at risk of invasion, as identified in Action 1.2.<br><br>A priority task is to monitor the 16 catchments identified at being of high risk of hymenachne invasion and establishment (Wearne et al. 2013). Habitat suitability modelling could be carried out using regional datasets to identify where within a catchment the high-risk areas are, and therefore reduce the area that requires ongoing monitoring.<br><br>Monitoring also needs to be carried out, or reported, for the current status of hymenachne invasion in the 24 catchments identified as high risk for spread and establishment (Wearne et al. 2013). | High priority<br>Ongoing | Surveys conducted for all 5 invasive grass species.<br><br>Many areas susceptible to invasion in northern Australia are sparsely populated. Incorporate monitoring into maintenance works or other surveys will assist in efficiently surveying in remote areas.<br><br>Outputs can be used to inform management actions in Objective 2, and to develop maps (Action 5.2) to communicate where management is required and how the distribution has changed over time.<br><br>Having an improved understanding of the current distribution, and how the distribution is changing will assist in knowing where to focus on spread prevention. |
| **5.2 National distribution maps**<br><br>Create updated national maps for hymenachne, para grass, annual mission grass and perennial mission grass. At a minimum this should include area of occupancy. An updated map of gamba grass density and distribution is currently under development. Maps need to be readily available in an online interactive spatial tool, so that the distribution of each threat can be overlayed with the distribution of threatened species and threatened ecological communities. | High priority<br>Short term | Publicly available national distribution maps for each invasive grass species produced and publicly available. This will improve stakeholder access to information on where key biodiversity assets are relative to invasive grasses. This will enable land managers to identify if these threats or abatement actions should be targeted in a specific area.<br><br>Updated maps and spatial data will enable changes to the invasive grass distribution since 2011 to be visualised. Outputs from this action to be used to inform actions in Objectives 1 and 2. |
| **5.3 Data standardisation**<br><br>Develop agreed data standards for invasive plant spatial data, and standardise monitoring protocols for invasive grasses.<br><br>This could include promotion of standardised collection of field data using the Atlas of Living Australia's BioCollect or the Ecological Monitoring System Australia (EMSA). EMSA is a series of best practice field monitoring protocols, a field app and data exchange system for collection and management of data. The EMSA Monitor app allows data to be easily uploaded to the Biodiversity Data Repository. | Medium priority<br>Medium term | Agreed invasive species spatial data attribute standards produced and applied by relevant stakeholders.<br><br>This will improve the understanding and measurement of the effectiveness of management actions and strengthen the evidence used to assess project outcomes. It will also facilitate better access to and re-use of survey data for adaptive management, research and policy.<br><br>This will make sharing of information between organisations easier, and to make reporting and collation of data at various scales (e.g. regional, state, national) easier and more efficient. |
| **5.4 Sharing of invasive grass spatial data within a central data repository**<br><br>Facilitate the sharing of mapping information (spatial data and meta data) between agencies and jurisdictions.<br><br>Create and maintain information on invasive grass abundance and distribution within a national database, such as the Biodiversity Data Repository (BDR), that is accessible to all jurisdictions, land management agencies and researchers. | High priority<br>Ongoing | Central dataset on distribution and abundance of invasive grasses accessible to all state and territory governments and agencies created.<br><br>Improved data management between government agencies and jurisdictions.<br><br>Increased management of invasive grasses across state borders and land tenures.<br><br>Increased capacity to monitor management and identify new incursions. |

| Action | Priority and timeframe | Output and outcome |
|---|---|---|
| **5.5 Monitoring and report management activities**<br><br>Encourage the monitoring and reporting of all invasive grass management activities, and the outcomes from management activities. Encourage invasive grass management programs to set targets for both reduction of invasive grass extent and improved trajectory of threatened species and/or improved condition of ecological communities.<br><br>Reporting on outcomes of management activities needs to include information that demonstrates the impact of the intervention, such as the area of grassy weed cover that has decreased. | High priority<br><br>Ongoing | Increase in the number of invasive grass management activities that are monitored and reported. Increased understanding of which management types are effective for controlling invasive grasses, and which management activities also improve the trajectory of threatened species or the ecological condition of an area.<br><br>Post control monitoring will allow the early detection of reinvasions and in the implementation of further control measures, with early control actions having a greater likelihood of success.<br><br>Analysis of monitoring outputs can be used as part of an adaptive management system to change management interventions for improved outcomes. |
| **5.6 Improved technology to detect and record**<br><br>Encourage the development, testing and promotion of new tools and technology to detect invasive grasses and to record and interpret data on weed distributions and management actions. This is particularly needed for determining infestation boundaries, and early detection of new incursions and range expansions of invasive grasses.<br><br>This includes refining existing techniques for detection and monitoring of grasses, such as using drones, automated image processing, algorithms to detect specific species and developing simple and affordable remote sensing protocols. | Medium priority<br><br>Long term | Improved tools and technology available to easily detect, record and interpret data on weed distribution and management actions. Tools available that can also be confidently used by most land managers, and not just specialists.<br><br>Earlier detection of new weed incursions will allow for early control and local eradication. |
| **5.7 Support Indigenous land management groups**<br><br>Provide support and resources for First Nations land management groups to undertake invasive grasses monitoring activities. Increase the capacity of First Nations people to participate in invasive grass management. | Medium priority<br><br>Ongoing | Training and information provided to interested land management groups. Groups have the necessary tools to monitor invasive grasses, and they know how to apply these tools confidently.<br><br>Increase in invasive grass monitoring, and an increased understanding of which management actions are having the desired outcomes.<br><br>Groups have key information at hand to help inform their yearly workplans. This action could be delivered through the regional invasive grass management networks (Action 6.3). |
| **5.8 Citizen science**<br><br>Encourage the community to carry out routine surveillance and reporting of invasive grasses using online national weed reporting webpages and apps. | High priority<br><br>Ongoing | Increased reporting of invasive grass sightings.<br><br>Improve accessibility of publicly available information on invasive grasses to support community coordinated action in surveillance and management activities. New incursions more likely to be quickly detected in populated areas, allowing quicker management intervention. |

# Objective 6: Increase awareness about invasive grass impacts and best practice management

Effective management of these 5 species of invasive grass across Australia requires a broad range of stakeholders, including the general public, to be aware of the problem, how their actions may contribute to spread of these grasses and the management options. There are numerous invasive plant species that land managers need to be aware of, and some land managers engaged during preparation of this plan perceived other invasive species to be of higher priority to manage, than the species in this plan (e.g. 'woody weeds'). Land management priorities vary enormously across northern Australia, but there is clearly a need for more education and awareness on the impacts of these grasses, with public awareness campaigns, education and citizen science all key parts of invasive species management (IPBES 2023).

The perception of these grasses as invasive species differs across Australia and between stakeholder groups, with 3 of the species still used commercially, particularly in Queensland. Divergence of perceptions of invasive alien species can prevent effective management (IPBES 2023).

Gamba grass was generally seen as the most important species of the 5 grasses to manage in the NT. In contrast, in Queensland, gamba grass was viewed by some stakeholder groups to be not as problematic as it is in the NT, and therefore there was no need to control it. This is not the case, and there is a significant risk of gamba grass spreading further in Queensland, with a large area of north Queensland being modelled as of high risk for gamba grass invasion (Pintor et al. 2019). The impacts of gamba grass need to be appropriately communicated to various groups in northern Queensland.

Hymenachne and para grass invade a different part of the landscape to the other invasive grass species in this plan: waterways, including wetlands and floodplains. There appears to be a lower awareness of hymenachne and para grass than gamba grass or the mission grasses, and many Indigenous ranger groups consulted had not heard of them. Some stakeholders refereed to hymenachne and para grass as a 'waterways problem' and thought they were not something they needed to manage.

The community can play an important role in contributing to the awareness and control of environmental weeds. For example, Gamba Grass Roots has helped to raise awareness of the threat posed by gamba grass to communities, tourism, landscape and wildlife in the NT. The Gamba Army, coordinated by Territory Natural Resource Management, are involved in gamba grass control, primarily herbicide application, within the Greater Darwin area. These groups, along with the Northern Territory government are helping to shift the public perception of gamba grass within the NT, from being a beneficial pasture species, to being an invasive weed. Communication strategies based on evidence can help to bring about community action on biological invasions by supporting the co-design of management actions, knowledge exchange and enhanced partnerships among stakeholders (IPBES 2023). Community support, as seen for gamba grass in the NT, is needed across all of northern Australia, and for the other invasive grass species as well.

There is some excellent existing invasive grass extension material, but stakeholders mentioned it could be hard to find the information they need. All existing, and new invasive grass management education material needs to be easily accessible to the general public and be available in both hard

copy form at public facilities (e.g. libraries, post offices, local government offices) and in digital accessible form. Some information has been developed with First Nations People, and this should continue, as well as key information being produced in language. Information could be handed out to land managers who engage with incentive programs, such as receiving free herbicide or borrowing spray equipment.

There is currently no single publicly available document or website that contains adequate up to date information for someone to manage one or more of these invasive grasses in protected areas or other natural environments for improved biodiversity or ecosystem condition. Most of the existing material takes a single species approach, which is unlikely to effective in the long term if other invasive plant species are present in the landscape. Gamba grass and the mission grasses can co-occur, and para grass and hymenachne are both present within numerous catchments. Aleman grass has been known to invade after para grass and hymenachne are controlled and this species is also a significant threat to the biodiversity of tropical wetlands (Queensland Parks and Wildlife Service 2022, pers. comm. 9 February). The production of updated best practice management guides that takes an integrated pest management approach is required.

Absentee landowners and owners of rural lifestyle properties, who are not dependent on farm income, are sometimes perceived to be less aware of land management obligations and less engaged with NRM agencies and other biosecurity organisations. Some people consulted were of the opinion that owners of small blocks of land (5 – 100 ha) who are not primary producers are not managing invasive grasses. There has been limited research on the values and priorities of rural lifestyle and absentee property owners in northern Australia. Studies in other parts of Australia show contrasting results, ranging from rural lifestyle owners having low biosecurity awareness and knowledge (Hollier et al. 2008), through to absentee landholders having similar invasive plant management practices to resident landowners (Gill et al. 2023).

During stakeholder engagement, it was repeatedly mentioned that there is a need for more field-based extension officers to assist in the identification of invasive grasses and to provide impartial advice on their management. In some rural areas, private-sector farm advisors are the only people readily available to offer advice to private landowners, and there is some concern around the effectiveness of privatised agricultural extension and potential conflicts (Nettle et al. 2018).

Para grass is not a declared weed in any jurisdiction in Australia, and annual and perennial mission grass are not declared weeds in Queensland. These species are considered as environmental weeds, or priority weeds in some catchments or local government areas, but this status has lesser implications for regulation and management than a declaration at a state or territory level. Gamba grass and hymenachne are both declared as weeds across northern Australia and are also recognised as Weeds of National Significance (WoNs). This means they have been identified as a national priority based on their invasiveness, potential for spread and environmental, social and economic impacts. Gamba grass and hymenachne have also been assessed as 'Plant species that are weeds' under the BICON Australian Biosecurity Import Conditions, such that new forms or varieties cannot be imported into Australia. This is, however, not the case for the other invasive grass species in this plan. Preventing the importation of new varieties of invasive grasses links to action under the first goal of the Australian Weed Strategy (commit to and continuously strengthen effective risk-based approaches to pre-border and border activities). Declaration as invasive weeds across all jurisdictions

where they occur will assist in raising the profile of these plant species as invasive and that they require management.

**Table 7 Actions for objective 6, increase awareness about invasive grass impacts and best practice management.**

| Action | Priority and timeframe | Output and outcome |
|---|---|---|
| **6.1 Weed declaration**<br>Encourage national recognition of the weed status of all 5 species of invasive grass in this plan through equivalent weed declaration in all the states and territories where they occur.<br>Gamba grass and hymenachne are declared weeds throughout most of Australia, but their classification varies with jurisdiction. Whereas para grass and annual mission grass are not declared as weeds in any jurisdiction. | High priority<br>Medium term | Collaboration between the Australian Government and state and territory governments to consistently identify all 5 grass species as highly invasive weeds under applicable state and territory legislation. Weed declaration would assist with compliance activities, prioritise management of these species and prevent further deliberate plantings. Weed declaration for para grass and the mission grasses would help prevent the importation of new varieties (Action 4.4).<br>Long term outcome would be invasive grasses managed more consistently, and management improved across the country. |
| **6.2 Invasive grass education**<br>Create and deliver invasive grass awareness and educational strategies with consistent messaging that appeal to the values and interests of rural lifestyle and absentee property owners. This can focus on landowners within the distribution of these grasses and aim to motivate landowners to take appropriate action. This should include the promotion of the gamba grass 3D model to assist with identification. | Medium priority<br>Long term – ongoing | Information developed and distributed on invasive grass identification and management, especially for rural lifestyle and absentee landowner within the distribution of these grasses.<br>Increased understanding if these groups of landowners are disengaged from natural resource management networks, or if it is just a perception.<br>Increased management of invasive grasses on small blocks that are not primarily used for agriculture, which will help prevent further spread. Increase awareness of invasive grass impacts, and how an individual's action could contribute or assist with the problem. |
| **6.3 Hymenachne and para grass awareness raising**<br>Increase the public's awareness of the impacts and the need to manage the semi-aquatic invasive grasses, hymenachne and para grass. These grasses rarely feature in Healthy Country Plans, and many Indigenous land managers gave uncertain answers about these species when surveyed. There is also a need to increase the profile of annual and perennial mission grass as invasive plants. Collating information on their impacts from Objective 1, will help tell a story of why they should be managed. | Medium priority<br>Long term – ongoing | Public education and awareness campaigns created and publicised. Public develop increased awareness of these invasive grasses and their adverse effects.<br>The public know where to get information to identify and manage these grasses, and have an increased awareness of how their own actions may contribute to the spread. Community's capability and willingness to participate in management increased. |
| **6.4 Tailored communication strategies**<br>Develop and deliver evidence-based communication strategies targeted at the general public, contractors and tourists visiting northern Australia that raise awareness of invasive grasses, the threats posed by them and instruct them on how to avoid contributing to their accidental spread. High-risk stakeholders include those operating vehicles performing roadworks, slashing and earthmoving, in or near conservation areas.<br>Information needs to be tailored to each stakeholder group to raise their awareness and increase their willingness to help. | Medium priority<br>Short term | Extension material developed and disseminated on preventing accidental invasive grass spread, with different material produced for high risk stakeholders and tourists.<br>Community ownership of the issue and increased awareness among stakeholders of the importance of managing invasive grasses.<br>Increase knowledge of the issue, leading to increased positive action. |

| Action | Priority and timeframe | Output and outcome |
|---|---|---|
| **6.5 Reduce agricultural promotion of invasive grasses**<br><br>Encourage the withdrawal of all extension material, including websites, that promote the agricultural use of gamba grass, para grass and hymenachne. | High priority<br><br>Short term | Consistent message on invasive grasses across extension material and websites from all relevant agencies. No further promotion of any of these invasive grass species for agricultural use.<br><br>Assist in preventing further deliberate planting of these species. Assist to promote the need to manage all existing plantings. |
| **6.6 Best practice manuals**<br><br>Develop comprehensive standalone best practice management manuals, with a focus on managing for improved biodiversity and ecosystem condition. At a minimum, one guide should be developed for terrestrial high biomass invasive grasses (gamba grass, annual mission grass and perennial mission grass), and a second guide for invasive semi-aquatic grasses (hymenachne and para grass) in northern Australia.<br><br>Guides need to differentiate between best practice management in conservation areas compared to urban and industrial areas and consider integrated pest management and outputs from Actions 7.7 and 7.8. | Medium priority<br><br>Medium term | Best practice management guides produced and made readily available in digital and hardcopy form.<br><br>Increased uptake of best practice management of these invasive grass species. Increase in invasive grass management carried out for improved biodiversity conservation outcomes. |
| **6.7 Field trails**<br><br>Field trials demonstrating best practice management methods for each grass species for improved biodiversity outcomes. These should also be documented and publicised. This has been done in the past for hymenachne but needs reinvigorating to engage additional land managers. | Medium priority<br><br>Long term | Field trials established, publicised and monitored. Field trials viewed by a range of land managers.<br><br>Increased awareness of best practice management, and increased uptake of best practice management for invasive grasses. |
| **6.8 Invasive grass management advice**<br><br>Encourage the deployment of more extension/field officers to educate land managers and the public on how to identify and best manage invasive grasses | Medium priority<br><br>Medium term | Increase availability of independent advice to those who need assistance with grass identification and invasive grass management.<br><br>Increased success and efficiency of invasive grass control work, increase local knowledge and confidence to address the problem.<br><br>In the long term, a decline in invasive grass abundance and distribution. |

# Objective 7: Improve invasive grass management through the development of new tools and understanding of interactions that facilitate invasion

Correct identification of invasive grasses is critical, as early detection and management of new incursions increases the probability of being able to successfully control them (see Figure 1). Invasive grasses are often overlooked or misidentified, especially if they are morphologically similar to native grasses, are at pre-flowering stage of development or are impacted by drought, overgrazing or mowing (Godfree et al. 2017). Furthermore, as mentioned in the genetics section below, some invasive grasses can display a range of morphological variations, making identification challenging. The native hymenachne (*Hymenachne acutigluma*) and the invasive hymenachne (*Hymenachne amplexicaulis*) are often confused, and the native hymenachne also gets misidentified as para grass. An interactive [3D model](#) of gamba grass has been produced by the NSW Department of Primary Industries. If the 3D model assists land managers and the public to correctly identify gamba grass, 3D models of the other 4 invasive grass species should be developed.

DNA barcoding can be used as part of a rapid genetic screen tool to identify grasses. NSW Department of Primary Industries have recently developed a field kit to identify serrated tussock (*Nassella trichotoma*) and Chilean needle grass (*Nassella neesiana*) in the field, which uses LAMP technology (loop mediated isothermal amplification) and DNA barcoding (Gopurenko et al. 2018; NSW DPI 2019). NSW DPI are aiming for the kit to become commercialised and available for sale. This technology could be adapted to allow the field identification of other invasive grasses, including gamba grass. There are no universal loci available for grass DNA barcoding, so multiple genes need to be examined to successfully identify a species. A range of gene fragments (e.g. ITS, matK, rbcL and trnL-F) have already been tested to correctly identify grasses from many different genera (Wang et al. 2022).

The gamba grass in Australia is known as cv. 'Kent'. This variety was developed in the Northern Territory by crossing plants that were thought to be var. *squamulatus* and a second unknown variety. Numerous stakeholders in Queensland and Northern Territory reported observing a wide range of morphological variation in gamba grass. Different phenotypes have also been observed by researchers within and between populations (Murphy et al. 2021).

Genetic studies could help explain these observations and the spread patterns of gamba grass within Australia. Murphy et al. (2021) proposed determining the ploidy level for different populations of gamba grass, and that a lack of genetic diversity may expose a 'weak link' in the biology of gamba grass. This weakness might be able to be exploited in control programs. Ploidy level refers to the number of sets of chromosomes in a cell or an organism. Ploidy levels are known to vary within some species of grass.

Biological control is one tool that can help achieve landscape-level sustained threat reduction of invasive plants, but it generally needs to be used in conjunction with other methods. Grasses are increasingly being targeted for biological control, with genetic and genomic tools assisting in finding effective biocontrol agents. There are some pastoralists who are opposed to biological control for gamba grass, however it is likely that a suitable agent would reduce the growth and biomass of

gamba grass rather than kill the plant (CSIRO 2021 pers. comm. 6 January). A broad range of the stakeholders consulted for the review of the 2012 TAP, thought the most effective control measure for invasive grasses would be biocontrol.

Some preliminary research on classical biological control agents for gamba grass and hymenachne has been undertaken. Currently, there are no known pathogens within Australia that impact these grass species, and it is most likely that an agent would come from the native range of these grasses. Cultivation of gamba grass may have separated the Australian gamba grass variety from natural biocontrol agents in its native range. Understanding the genetics of Australian gamba grass would assist in finding suitable agents in southern Africa for potential use in Australia.

Control of these grasses is largely reliant on the use of non-selective herbicides, particularly glyphosate in spray form. There have been no reports of glyphosate resistance in these species, but there is a risk of herbicide resistance due to the large reliance on it. One approach to reduce the risk of glyphosate resistance is to use a range of herbicides with various modes of action.

Another hurdle for invasive grass management in northern Australia, is access to the plants in the wet season when they are actively growing (WA DBCA 2022 pers. comm. 19 September). Hymenachne and gamba grass are on track for eradication in Western Australia, as the plants were accessible all year round and crocodiles did not occur in the areas where these species were found (WA DBCA 2022 pers. comm. 19 September).

There have been several herbicide trials focused on gamba grass and mission grass (Murphy et al. 2021, Vogler et al. 2021, Luck et al. 2019), but so far, no suitable alternative to glyphosate has been found. Glyphosate is non-selective, meaning it kills most plants and not just the targeted grasses. Velpar granules (active ingredient hexazinone) have cautiously been used within gamba infestations. The rain activated granules allow spot application in the dry season, but this herbicide is also not grass specific, can kill trees and cannot be used in riparian areas.

Currently land managers need to trade-off significant off target effects for effective invasive grass control (Murphy et al. 2021). Research and development into grass specific soil residual herbicides is required. A soil residual herbicide could be applied late in the dry season or early in the wet season when site access is still possible, causing mortality to adult plants and controlling seedlings as they appear during the wet season. At smaller scales, a lightweight, residual pellet herbicide is needed that can be carried by land managers searching for satellite incursions or while carrying out other works (Murphy et al. 2021). A pellet or granular form would allow the herbicide to be carried in backpacks and be applied where required by hand, or be delivered by drones in hard to access areas. Testing of other chemical adjuvants, substances added to a herbicide to improve the effectiveness of a herbicide, could also be undertaken to improve performance of existing herbicides that have shown some impact.

The grass specific herbicide flupropanate is currently the most promising alternative to glyphosate for gamba grass and mission grass control (Murphy et al. 2021; Vogler et al. 2017). The granular form of flupropanate requires further testing at different rates in a range of soil and vegetation types. Flupropanate is currently not registered with the Australian Pesticides and Veterinary Medicines Authority (APVMA) for use on any of these grass species. There are also many other herbicides that require further testing on these invasive grasses (e.g. clomazone, oxyfluorfen and indaziflam).

Re-establishment of invasive grass infestations from the soil seed bank is a problem for all of these species, with seed surviving between 1 to 8 years in the soil (see Table 2 of the Background Document). Several soil residual herbicides have been identified that need further testing for use within gamba grass infestations (e.g. dalapon, sulfometuron, terbacil, sulfometuron and imazapyr), with efficacy possibly related to soil properties and climatic conditions (Luck et al. 2019; Murphy et al. 2021).

Many of the herbicides used to control hymenachne and para grass are only approved under off-label minor use permits (e.g. haloxyfop, fluazifop and glyphosate). These permits are usually issued for a set period of time. Full registration and approval of these herbicides for use on these grasses with the APVMA would alleviate land managers concerns the permits would not be reissued and reduce the administrative burden on the state agencies that need to frequently reapply for these minor use permits.

It has been observed that the hybrid *Hymenachne × calamitosa* is harder to kill with glyphosate than *Hymenachne amplexicaulis* (QPWS 2022 pers. comm. 2 February). It is not known how invasive this hybrid is, if it is a threat and if it is spreading. The impact of the hybridisation on populations of the native hymenachne, *Hymenachne acutigluma*, in the NT and Queensland is also not known.

Fire is promoted in various extension material as a means of controlling all 5 invasive grass species. This is to reduce the grass biomass prior to herbicide application, remove dead biomass after herbicide application or expose seedlings and reshoots of para grass and hymenachne for follow up herbicide application (Clarkson 2012). Fire alone will not kill hymenachne (Clarkson et al. 2012), para grass (Grice and Nicholas 2011) or gamba grass (NT Government 2023). Fire as a tool on its own can be problematic for controlling gamba grass and the mission grasses, as these plants are encouraged with repeated burning, a process known as the grass fire cycle (see section 1.3). Indigenous consultation carried out for this plan, indicated that gamba grass and mission grasses were increasing the risk of destructive fires, and concerns were common around inappropriate fire management, and fire damaging sacred sites and painting galleries. Indigenous rangers and Traditional Owners also expressed there was a lack of consultation with them on fire management.

More research and field trials are required on the role of fire for the management of gamba grass and the mission grasses in conservation areas. The decline in trees in savanna woodlands is not correlated with the time since invasion by gamba grass and mission grass, but by the fire management following invasion (Brooks et al. 2010). Invasive grass researchers consulted commented that in general it is best not to burn invasive high biomass grasses, as burning facilities further germination and spread. Field trails in Mary River National Park within savanna woodlands invaded with gamba grass show that exclusion of fire for a number of years could be beneficial to managing gamba grass for conservation outcomes (Rossiter-Rachor and Setterfield 2019). In the absence of fire, the health of the gamba grass declines, tree health increases, and the increases in tree canopy cover reduces the sunlight reaching the gamba grass. The increase in tree canopy helps maintain a dense layer of leaf litter, which inhibited the germination of gamba seeds (Rossiter-Rachor and Setterfield 2019). In the northern Australia savannas, it can however, be very challenging to exclude fire for multiple years.

Best practice invasive grass management will differ in urban and conservation areas, with fuel reduction more critical in urban areas because of the risk to people and infrastructure. The long-term

effects of fire exclusion for gamba and mission grass management need to be investigated and demonstrated in a range of invaded vegetation communities, as does an integrated approach to cultural management of these species (Murphy et al. 2021). Demonstration of best practice management of gamba grass and mission grass for conservation outcomes is also required to help improve uptake of appropriate management.

Hymenachne and para grass are very difficult to control on the floodplains of northern Australia. Fire in the late dry season has been used as a tool to reduce the biomass of hymenachne and para grass in seasonally inundated wetlands (Grice and Nicholas 2011). Herbicide and grazing are also used to manage hymenachne and para grass. Bare areas created by management activities are colonised by both invasive grasses and native wetland plants. Research is required on the successional processes after extensive weed control on wetlands and to determine how the recovery of native species can be facilitated to minimise reinvasion (Grice and Nicholas 2011). The seed bank of wetlands in Queensland invaded by para grass for more than 30 years contained viable seeds for only one or 2 native species, and wetland areas with deeper water, that do not have dry periods, are also less likely to be restored from the soil seed bank (Wearne et al. 2011). In wetlands that have been invaded for a long time, revegetation may be required after invasive plant management. This is important to ensure that gaps created through management activities are not reinvaded by another invasive species, especially if the native seed bank is depleted. There have been no reports or publications addressing the long-term success of hymenachne or para grass management programs that also included seed addition or planting. Tube stock planting is expensive and appears to only have been done in very small areas following reduction of invasive aquatic grasses.

Para grass can increase in cover when there is a decrease in fire on the floodplains (Ferdinands et al. 2005), and there has been a general reduction in traditional burning practices on the floodplains of northern Australia. Some of this is because people are coming off country, and there has been less burning to maintain native plant diversity (Territory NRM 2021, pers. comm. 28 January 2021), and because para grass is being retained as cattle fodder. During the consultation for this plan, numerous Indigenous rangers mentioned that invasive grasses physically prevented them from accessing Country, with one ranger commenting that it was 'difficult to take elders out to where they use to go to when young'. Adams et al (2018) also found that para grass was restricting physical access to Indigenous bush tucker. It is not known if reduced accessibility to wetlands or the presence of para grass and hymenachne and their impacts on fire properties is also contributing to the disruption of cultural burning practices on wetlands.

Indigenous rangers commented during consultation that knowledge about interactions between different invasive plants, and between feral animals and weeds is lacking. One ranger group raised concerns around the relationship between *Mimosa pigra* (giant sensitive plant) and hymenachne. Rangers thought that hymenachne could be keeping the soil moist for an extended time at the start of the dry season, and this could be benefiting the mimosa plants. Mimosa is a Weed of National Significance and invades extensive areas of wetlands in northern Australia. Para grass was once deliberately planted to suppress the regrowth of mimosa following herbicide application, and hymenachne has also been proposed as a suppressant for mimosa but does not appear to have been extensively planted for this reason.

Gamba grass is known to be spread by large herbivores such as Asian water buffalo (*Bubalus bubalis*) and feral pigs (*Sus scrofa*), and there have been comments and anecdotal evidence to suggest that feral pigs and their ground disturbance around permeant and semi-permeant water bodies may also facilitate para grass and hymenachne establishment. Pig disturbance is thought to be able to stimulate germination of buried hymenachne seeds, years after successful herbicide control of adult plants (NT Department of Environment, Parks and Water Security 2022 pers. comm. 25 July).

Grazing by water buffalo may help keep para grass and hymenachne under control. However water buffalo may spread vegetation fragments into new areas and create a lot of disturbance around wetlands and floodplains, which may facilitate further invasion. There have been observations within Kakadu National Park and east Arnhem Land, of hymenachne and para grass biomass increasing following control of water buffalo (Boyden et al. 2018, Pettit et al. 2011, NAQS 2021 pers. comm. 14 December). These interactions need to be considered as part of an integrated pest and weed management approach, such that the removal of one threat does not lead to an increase in another.

Ponded pasture systems were created in saltmarshes and melaleuca and eucalyptus coastal tree swamps of coastal Queensland, particularly along the dry tropical coast of the Great Barrier Reef. Ponded pasture involves creating artificial wetlands and modifying existing wetlands by constructing banks (bund walls) to retain freshwater and surface run-off. These systems were often planted with hymenachne, para grass and Aleman grass. Hymenachne and para grass both prefer fresh water, and there have been a limited number of studies examining the impact of bund wall removal, or the introduction of saltwater bores, to help control para grass and hymenachne. Bund wall removal can improve water quality and bird and fish communities, but the impact on freshwater weeds in the long term is less certain (Abbott et al. 2020, Reid et al. 2018). Following bund wall removal, invasive grass cover can fluctuate in response to rainfall and extent and frequency of tidal ingress (Karim et al. 2021). More saltwater tolerant invasive grasses may also increase in cover, such that there is a change in composition of invasive grasses but not an overall decrease in their total cover (Waltham et al. 2019). Long term monitoring of existing projects and additional trials are required, and there is a need to determine what other management approaches are best used in conjunction with bund wall removal for long term reduction in invasive grasses.

**Table 8 Actions for objective 7, improve invasive grass management through the development of new tools and understanding of interactions that facilitate invasion.**

| Action | Priority and timeframe | Output and outcome |
|---|---|---|
| **7.1 Genetic variability in gamba grass**<br>Conduct research to understand the genetic variability in gamba grass, and if this relates to the observed variation in morphology, invasiveness and susceptibility to different control methods. | Medium priority<br>Short term | Understand the role of genetic variation in gamba grass invasions, and if certain genetic profiles are 'weedier'. Understand if there is a 'genetic weakness' that can be exploited to help manage gamba grass. Determine if Qld and NT populations are genetically similar and were likely to come from the same source population. This information will help determine if there are different gamba grass varieties in Australia and if they require different management. The genetics of gamba grass will assist with identifying suitable biocontrol agents (Action 7.6). |
| **7.2 Climate change impacts**<br>Undertake research to understand if the rate of spread and ecological impact of all 5 species of invasive grass will change under climate change. For example, determine under climate change scenarios, if the growing season for gamba grass will become longer and lead to an increase in biomass. | Medium priority<br>Short term | Research conducted increasing our understanding if the ecological impacts and rate of spread of these invasive grasses is likely to change under future climate conditions. This information can be used to prioritise areas for management, inform best practice management and in education and communication products. |
| **7.3 Best practice management**<br>Determine the best practice management for the hybrid *Hymenachne × calamitosa*. This includes the most appropriate use of herbicide and fire for positive biodiversity outcomes.<br>This priority of this action is dependent upon the outputs from Action 1.6. If ecological impacts of this hybrid are high, the priority for this action should be increased. | Low priority<br>Medium term | Improved understanding of the best way to manage *Hymenachne × calamitosa* in conservation areas for improved biodiversity outcomes.<br>Best practice management guidelines to be communicated to key stakeholder groups (Objective 6) to promote uptake and improved management. |
| **7.4 Grass identification tools**<br>Encourage the development of novel grass identification tools such as 3D grass plant models, interactive web-based tools using artificial intelligence, and a rapid invasive grass identification kit using DNA barcoding. | High priority<br>Long term | One or more tools developed, publicly available and promoted. Identification tools are applied to increase the confidence in invasive grass identification, especially when botanical expertise is unavailable.<br>Use of identification tools could allow for early detection (pre-flowering) of invasive grasses which allows quicker and more cost-effective management. |
| **7.5 Herbicide testing and development**<br>Undertake research and development into new herbicides and chemical adjuvants for improved control of invasive grasses. This could include a. testing of herbicides not currently registered for these species, b. development of a new grass selective herbicide, c. development a pre-emergent herbicide, d. development of delayed action lightweight pelleted or granular form of herbicide.<br>APVMA approval would be required for any new herbicide, or for use of an existing herbicide in a manner different to the original approval. | High priority<br>Long term | More invasive grass control options available, including an effective alternative to glyphosate.<br>A pre-emergent or delayed action light weight granular or pelleted herbicide is available, allowing land managers to easily carry and apply treatment as new infestations are detected, and allowing application in late in the dry season or early in the wet season when there is still good site access.<br>This would ultimately lead to improved invasive grass control. |

| Action | Priority and timeframe | Output and outcome |
|---|---|---|
| **7.6 Biological Control**<br><br>Promote research into biological control agents for each of the grass species. This includes conducting bioclimatic analyses, carrying out host range specificity surveys, cataloguing potential biocontrol species, assessing feasibility of potential agents and undertaking screening of species of agricultural and environmental importance to determine any off-target impacts. Genetic analysis outputs from Action 3.1 could be used to guide agent selection, with additional genetic analyses also required. | High priority<br>Ongoing | Understand if biological control is a viable option for any of these grasses. A catalogue of potential agents produced, and commencement of host specificity testing.<br><br>Successful biological control programs take 5 to 10 years, with host specificity testing alone taking several years. This means that this action will be ongoing beyond the life of this plan. |
| **7.7 Integrated pest management**<br><br>Encourage integrated pest management of wetland weeds and pigs and water buffalo. Immediately following buffalo removal, treat and monitor any hymenachne and para grass in the area. Following the management of hymenachne, feral pigs in the area are also managed. | Medium priority<br>Ongoing | Development and trialling of integrated pest management strategies.<br><br>Coordinated action on invasive aquatic grasses and herbivores undertaken.<br><br>Improved long term outcomes for invasive grass management programs on wetlands and floodplains. |
| **7.8 Mimosa invasive grass interactions**<br><br>Undertake field investigation to understand if *Mimosa pigra* benefits from growing near invasive aquatic grasses. Determine if hymenachne should be controlled at the same time as mimosa, to improve outcomes of mimosa control. | Low priority<br>Medium term | Improved understanding if this threat interaction is occurring, and if it is important to manage these 2 invasive species at the same time for improved outcomes. |
| **7.9 Fire exclusion**<br><br>Undertake research and field trials to better understand fire exclusion for several years as part of an integrated management approach for gamba grass and mission grasses in conservation areas. Monitor to determine if there are any benefits to biodiversity or ecosystem recovery. | High priority<br>Long term | Fire exclusion has been successfully demonstrated as a tool for gamba grass control in one conservation area, but uptake oft this methodology has been low. Demonstration across multiple sites or land tenures, documenting and communicating any benefits to ecosystem recovery and threatened species could assist with uptake. |
| **7.10 Impacts on cultural burning**<br><br>Engage with First Nations people to understand if these introduced grasses have changed their cultural burning practices. | High priority<br>Short term | First Nation people, including Indigenous rangers, consulted on if/how invasive grasses impact cultural burning practices. Understand if there are any insights into invasive grass burning practices that are more appropriate for conservation of cultural assets. |
| **7.11 Alternative management options**<br><br>Research alternative management options for improving biodiversity in areas where invasive grass management is prohibitive, such as where reinvasion occurs. This could include management aiming to restore vegetation structure, reintroduce habitat heterogeneity or openness. For example, does keeping some parts of invaded wetlands clear of para grass and hymenachne improves habitat quality for wildlife and increases connection with country for First Nations people. | Medium priority<br>Long term | Knowledge of alternative management option(s) that improve the trajectory of threatened species impacted by one or more of these invasive grasses.<br><br>An alternative management option(s) that is ready to be trialled at a larger scale across multiple conservation areas. Having such an option is important for para grass and hymenachne invaded areas, especially where landowners in the upper catchment would not participate in management and reinvasion is likely, and where previous management has been unsuccessful. |

| Action | Priority and timeframe | Output and outcome |
|---|---|---|
| **7.12 Bund wall removal in Queensland**<br><br>Conduct new field trials on bund wall removal in coastal areas of Queensland and encourage long term monitoring of existing bund wall removal projects to determine the long term benefits of bund removal and saltwater intrusion on invasive grass cover and species composition. Determine what other management techniques are best used in conjunction with bund wall removal for long term reduction in invasive grasses. This includes determining if saline groundwater (bore water) could be used to supplement tidal ingress to manage para grass and hymenachne in waterways without impacting other aspects of the ecosystem (e.g. water quality). | Medium priority<br><br>Long term | Outcomes for invasive grass cover and abundance in waterways following bund wall removal are currently variable. Findings from long term monitoring could inform what needs to be done to improve long term outcomes for coastal aquatic ecosystems that were once used for ponded pasture. |
| **7.13 Recovery of native vegetation within long invaded wetlands**<br><br>Undertake research and trials to improve the outcomes for successional processes after extensive weed control on wetlands. This includes determining if the recovery of native plant species can be facilitated to prevent weeds from reinvading.<br><br>Trial and monitor revegetation (seed or tube stock) after control of para grass and/or hymenachne from areas that have been invaded for a long time (>30 years invaded). Determine if revegetation improves the long-term control of para grass and hymenachne and improves biodiversity outcomes. | Medium priority<br><br>Long term | Research and trials commenced and monitored.<br><br>This action will take many years, and outcomes are likely to be in more than 5 years. The ultimate outcome is management options available for increased native vegetation diversity and cover after control of long term para grass and/or hymenachne invasions in aquatic ecosystems. |

# 3   Investment and implementation of the plan

This plan reflects the ongoing and adaptive nature of the threat abatement process.  Proposed actions may be modified over the life of the plan as knowledge develops and the effectiveness of actions is evaluated.

Regional or local eradication (extirpation) and eradication from some islands could be possible for gamba grass and the mission grasses but there is no likelihood of nationally eradicating these 5 invasive grass species in the foreseeable future. This is especially the case given 3 of the 5 species are still used agriculturally. The plan identifies 55 actions, each with a priority level and timeframe for implementation. The plan's 26 high priority actions should be the initial focus of implementation, but we note that the priority of each action could vary with stakeholder values, and a range of stakeholders will be involved in the implementation. Activities range from short term, through to actions that will be required long term, such as actions focused on preventing spread and reinvasion of the invasive grasses to priority sites.

The actions identified in the plan may be reviewed at any time, but must be reviewed by the Australian Government within 5 years of the plan being made or varied.

## 3.1   Investment in the plan

The provision of adequate and sustained resourcing greatly improves the effectiveness of actions for long-term management of biological invasions (IPBES 2023). Australian Government funds may be available to implement key national environmental priorities, however stakeholder partnerships and co-investment will be key to the successful implementation of this plan.

This plan provides a framework for prioritising investment in threat abatement and will help direct Australian Government funding programs to activities that will assist with the objectives and actions of the plan. The Australian Government has an obligation to implement the plan to the extent to which it applies in Commonwealth areas. There is also potential for some of the actions to be co-funded.

### 3.1.1   Costing

Estimating the cost of individual actions described in this plan, and across all actions in the plan in its entirety, is challenging. Costs will vary greatly depending on many factors including the scale of implementation of actions, the duration and intensity over which they are required, or the remoteness, access or other logistic considerations of the location. Costs will generally be higher in more remote or less accessible locations. Many of the actions detailed in this plan are linked and dependent upon output from other actions.

Managing established weeds is a shared responsibility between landholders, community, industry and government. On-ground management is primarily the responsibility of state and territory governments and land managers. Investment in actions of the plan will be determined by the priority

and level of resources that stakeholders commit to management of the threat. Partnerships among and between governments, non-government organisations, industry, community groups, First Nations people and individuals will be key to successfully delivering significant reduction in the threats posed by these invasive grasses.

The management of invasive grasses and recovery of the species and ecological communities they impact will already be incorporated in some existing plans. New and revised Ramsar wetland management plans and recovery plans and conservation advices for threatened species and ecological communities should incorporate invasive grass management, where appropriate.

**Cost of delayed action**

The invasion curve provides an indication on the economic return on investment for each stage of weed invasion (Figure 1). The cost-benefit of invasive plant management decreases as invasion progresses, with actions carried out to prevent invasion and spread being the most cost effective. There are also significant environmental costs to not acting on the threat of invasive grasses. Invasive grass infestations are generally cheaper to control, if control is implemented as soon as the infestation is detected. For example, in Litchfield National Park, if intensive control of gamba grass was implemented in 2014 after a gamba grass survey was completed, eradication was estimated to cost $82,000 a year, with a total cost of $410,000 over 5 years (2021 dollars). In 2021, the cost for eradicating gamba grass from the same surveyed area increased to $825,000 ± $16,000 over 5 years ($165,000 ± $2500 per year) due to the increase in gamba grass cover from lack of action (Rossiter-Rachor et al. 2023).

The stage of the invasion curve these grasses are at, varies with location, and to some extent, how long the species has been naturalised in Australia. For para grass and hymenachne in the NT and far north Queensland, they are at the asset-based protection stage. However, for the southern limit of their distribution, localised eradication could be possible, and prevention should be a focus for uninvaded areas. The limited data available, suggests all these invasive grasses are still spreading, and they have not reached their full modelled potential distribution. This indicates there is still some ability to contain them, and for local eradication, such as from islands and protected areas with a low risk of reinfestation. Preventing new incursions of gamba grass and hymenachne in WA is a priority, with eradication programs progressing well.

**Cost of invasive grass management**

The net cost of invasive grass management is difficult to estimate and will depend upon the area being treated, control methods, ease of access to the site, size and longevity of the seedbank, and the density of the grass infestation. The per unit costs are higher for low density or scattered invasive plants as the effort spent searching is greater, and a bigger distance must be covered to treat an equivalent area (McMaster et al. 2014).

Management options include grazing, burning, fire exclusion, herbicide application, chipping, mechanical removal, flooding and bund wall removal. Often an integrated management approach will be needed, using a combination of these methods. For more details on management options see Chapter 2 and 3 of the Background Document.

The herbicides registered for use for each grass species varies between jurisdictions. Herbicides are registered by the Australian Pesticides and Veterinary Medicines Authority (APVMA), and their use is governed by both Commonwealth legislation (*Agricultural and Veterinary Chemicals Code Act 1994*) and various state and territory legislation. The cost of herbicide treatment varies will the application rate, the formulation and application method (e.g. hand, vehicle, helicopter). For example, to treat one hectare of gamba grass with glyphosate can cost less than $100, whereas flupropanate could be over $1,000, excluding labour (Luck 2017).

Ecosystems heavily invaded with invasive grasses for a long time would need active restoration if the native species' soil seed bank was inadequate. This would be an additional cost. The cost of revegetation depends on numerous factors including how degraded the vegetation is. For example, it would be more expensive to restore savanna woodland where most trees and shrubs have been killed by intense gamba grass fires, than to restore a vegetation community where the trees are still present. The National Restoration Standards set the guiding principles for ecological restoration and rehabilitation in order to deliver ecologically appropriate environmental repair. These standards can help guide revegetation after invasive grass control.

**Cost of para grass control with herbicide**

High levels of herbicide sprayed over 562 km$^2$ of para grass infestation were estimated to cost $0.32 million per year ($570 per square kilometre) and would cost approximately $6.35 million for 20 years of treatment (Cattarino et al. 2018). Low level of herbicide spraying over 207 km$^2$ of para grass infestation were estimated to cost $0.19 million per year ($920 per square kilometre) and cost $3.72 million for 20 years of treatment (Cattarino et al. 2018).

A single herbicide treatment for para grass across all the Kakadu floodplains was estimated to cost $2.91 million in 2023 dollars (26.7% increase, RBA inflation rate applied), and take the equivalent of 48 people working full time for a whole year (McMaster et al. 2014).

There have been no updated management costs published for herbicide treatment of hymenachne since 2010, but these would be similar to the cost for para grass. Management of para grass and hymenachne, like other aquatic weeds, needs to be considered within the context of the catchment which the waterway or floodplain sits within.

**Cost of gamba grass control with herbicide**

Eradication of gamba grass from a 74,331 ha area in Litchfield NP was estimated to cost $7,140,000 ± $64,800 over 10 years, with this including a 5 year eradication phase and a 5 year maintenance phase (Rossiter-Rachor et al. 2023).

The eradication phase was estimated to cost $6,585,000 over 5 years and require 7650 ± 29 labour hours per year. This is approximately $1,800 per square kilometre per year. The maintenance phase was estimated to cost approximately $555,000 over 5 years. This includes an annual aerial survey ($23,000 per year) to identify new incursions and to deploy immediate ground control. This would take 467 ± 67 labour hours of ground control spraying with glyphosate (~$88,000 per year in labour equipment and chemicals) (Rossiter-Rachor et al. 2023).

The costs for eradicating one or both of the mission grasses would be similar to the cost for gamba grass. Efficiencies would come from targeting all 3 species at the same time where they co-occur.

## 3.2    Information for regulators

Assessments of development proposals should consider the potential consequences of the development on the increase in abundance or spread of these grasses, particularly in natural environments. Developers should determine if these invasive grass species are present in or near the area, and if the area is suitable habitat for any of these invasive grass species. Current habitat suitability can be checked by consulting maps on the Weed Futures website for gamba grass, hymenachne and para grass, or the maps for each grass species within Chapter 2 and 3 of the accompanying Background Document.

Transport corridors and are a major spread pathway for weeds (Laidlaw et al. 2017), including invasive grasses (Ngugi and Neldner 2017). Riparian corridors are also spread pathways for invasive grasses, and provide suitable habitat for gamba grass (Rossiter-Rachor et al. 2023), hymenachne and para grass (Boyden et al. 2019; Wearne et al. 2010). Movement of construction materials, vehicles and equipment contaminated with seeds or vegetation fragments can easily spread invasive grasses. Examples of actions that have high risk of unintentional weed spread or increase the probability of weed establishment include:

- Construction of corridors through natural environments (e.g. roads, gas, power, communications or water infrastructure), especially where vehicles and machinery need to travel through areas invaded by invasive grasses.
- Soil disturbance and vegetation clearance, particularly in riparian areas.
- Mines and other extractive industries (sand, gravel, soil, fill) – high risk of unintentional movement of seeds, plants and plant parts and invasion into cleared areas.
- Gravel pits – these frequently become contaminated with invasive grasses and become a source of seeds.
- Construction of feedlots which use gamba grass fodder.

## 3.3    Implementing the plan

This threat abatement plan provides a framework for undertaking targeted priority actions. As knowledge develops, proposed actions may be modified over the life of the plan. The Australian Government is committed, via the EPBC Act, to implement the threat abatement plan to the extent to which it applies in Commonwealth areas. In addition, Australian Government agencies must not take any actions that contravene a threat abatement plan. Where a threat abatement plan applies outside Australian Government areas in states or territories, the Australian Government will seek the cooperation of relevant jurisdictions, with a view to jointly implementing the plan.

When resources are limited, outcomes from the management of biological invasions are enhanced when all stakeholders are actively engaged (IPBES 2023). Successful implementation of this plan will depend on a high level of coordination, regional planning and cooperation between all key stakeholders, across different land tenure types in all jurisdictions, including:

- Australian Government departments and agencies
- state and territory environment, agriculture and natural resource management agencies
- local governments
- First Nations people, including Indigenous Protected Areas, land councils and Indigenous ranger groups
- research organisations and universities
- threatened species recovery teams
- non-government environmental organisations and private conservation land management bodies
- the general community, including private landholders.

This threat abatement plan follows and benefits from the previous threat abatement plan, released in 2012. However, the ongoing need for such plans shows that this key threatening process is challenging to abate, and will require long-term investments in research and management, and long-term support from key stakeholders and the public.

## 3.4    Evaluating the plan

This threat abatement plan needs to be reviewed at intervals of no greater than 5 years as specified by the EPBC Act. The review will examine progress towards each of the actions and assess whether the plans objectives have been met. The review will also evaluate the plan's implementation success, specifically whether activity under the threat abatement plan has resulted in:

- reliable mapped distributions being available for each invasive grass to underpin management
- a decrease in abundance and geographical distribution of these invasive grasses
- a decrease in number of new satellite infestations

- improvement in the condition of threatened ecological communities impacted by these invasive grasses

- improvement in the population trajectory and extent of occurrence of threatened species populations impacted by these invasive grasses

- improvement in the condition of Country

- a decrease in invasive grasses preventing access to Country.

An improved understanding of the threat the 5 invasive grasses pose could be indicated by an increase in the number of;

- Healthy Country Plans referencing these invasive grasses and/or the threat abatement plan

- Commonwealth, state, regional and local government plans and strategies referencing the threat abatement plan

- grant applications applying for funding to manage these grasses

- people volunteering to help manage these grasses or the species they impact

- enquiries land care groups, local land services, NRM groups and local and state government agencies receive about how to identify and effectively manage these invasive grasses.

The recommendations and findings of the threat abatement plan review will form the basis of a decision about when to revise the plan, if required.

# 4 Abbreviations

| Abbreviation | Meaning |
| --- | --- |
| APVMA | Australian Pesticides and Veterinary Medicines Authority |
| DPI | Department of Primary Industries |
| EPBC Act | *Environment Protection and Biodiversity Conservation Act 1999* |
| IPA | Indigenous Protected Area |
| KTP | Key threatening process |
| NAQS | National Australian Quarantine Service |
| NSW | New South Wales |
| NRM | Natural Resource Management |
| NT | Northern Territory |
| Qld | Queensland |
| TAP | Threat abatement plan |
| WA | Western Australia |
| WoNs | Weeds of National Significance |

# 5 Appendix

## Appendix A. Species and ecological communities impacted by the invasive grasses

Australian species considered to be at risk of extinction can be included in the list of threatened species established under the EPBC Act as either Vulnerable, Endangered or Critically Endangered, to reflect their risk of extinction. Information on EPBC Act listed threatened taxa and the processes that threaten them were obtained through the Species Profiles and Threats Database (SPRAT), scientific literature, threat abatement plans, conservation advices, recovery plans, listing advices and consultation with experts (Table A 1). Under the EPBC Act a threat is a process that threatens or may threaten the survival, abundance or evolutionary development of a native species or ecological community. Ecological communities threatened by these invasive grasses, and world heritage properties, national heritage places and wetlands of international importance (Ramsar wetlands) where these invasive grasses are a known or possible threat are outlined in Table A2.

**Table A1 Species known or thought to be impacted by the invasive grasses in this plan. If the specific invasive grass species threat to a species is known, it is listed. Species are listed as either critically endangered (CR), endangered (EN) or vulnerable (VU) under the EPBC Act.**

| Scientific name | Common name | EPBC Act status | Grass threat (If known) | Notes |
|---|---|---|---|---|
| **Birds** | | | | |
| *Amytornis woodwardi* | white-throated grass wren | VU | - | Increased extent and frequency of fire due to invasive grasses a possible threat |
| *Chloebia gouldiae* (Previously *Erythrura gouldiae*) | Gouldian finch | EN | gamba grass, mission grasses | Invasive pasture grasses exacerbate fire impacts, and replace native grasses that may provide key food resources (Woinarski and Winderlich 2014) |
| *Epthianura crocea tunneyi* | yellow chat (Alligator Rivers) | EN | hymenachne, para grass, gamba grass | Conservation Advice |
| *Epthianura crocea macgregori* | yellow chat (Dawson) Capricorn yellow chat | CR | hymenachne, para grass, gamba grass | Recovery Plan; Woinarski et al. (2007) |
| *Erythrotriorchis radiatus* | red goshawk | VU | - | Invasive grasses exacerbate fire impacts (Woinarski and Winderlich 2014) |
| *Falcunculus frontatus whitei* | crested shrike-tit (northern) | EN | gamba grass | Conservation Advice; Crowley (2008). Introduced pasture grasses increased intensity of fires. |
| *Geophaps smithii smithii* | partridge pigeon (eastern) | VU | gamba grass, mission grasses | Changed fire regime due to invasive grasses |

| Scientific name | Common name | EPBC Act status | Grass threat (If known) | Notes |
|---|---|---|---|---|
| *Geophaps smithii blaauwi* | partridge pigeon (western) | VU | gamba grass | Conservation Advice |
| *Malurus coronatus coronatus* | purple-crowned fairy-wren (western) | EN | - | TAP (2012) |
| *Melanodryas cucullata melvillensis* | hooded robin (Tiwi Islands) | CR | gamba grass, mission grasses | Listing Advice. Changed fire regimes due to invasive grasses |
| *Mirafra javanica melvillensis* | Horsfield's bushlark (Tiwi) | VU | - | Changed fire regime due to invasive grasses |
| *Poephila cincta cincta* | back-throated finch (southern) | EN | - | Recovery plan |
| *Psephotus chrysopterygius* | golden-shouldered parrot | EN | gamba grass | Listing Advice for grasses KTP; Cape York NRM (2011); Grice et al. (2013). Change of vegetation composition and structure leading to loss of nesting, feeding and roosting sites. |
| *Tyto novaehollandiae kimberli* | masked owl (northern) | VU | gamba grass, mission grasses | SPRAT; Rossiter et al. (2003) |
| *Tyto novaehollandiae melvillensis* | masked owl (Tiwi Islands) | EN | mission grass | Recovery Plan |
| **Mammals** | | | | |
| *Antechinus bellus* | fawn antechinus | VU | gamba grass | Invasive grasses are a probable threat via changed fire regimes |
| *Conilurus penicillatus* | brush-tailed rabbit-rat | VU | gamba grass, mission grasses | Listing advice |
| *Dasyurus hallucatus* | northern quoll | EN | gamba grass, mission grasses | Recovery Plan; Woinarski and Winderlich (2014)<br><br>Invasive grasses change vegetation structure which may inhibit ground movements and hunting. More intense fire may cause direct mortality, reduce availability of shelter and reduce habitat heterogeneity. |
| *Mesembriomys gouldii gouldii* | black-footed tree-rat *(Kimberley and mainland)* | EN | gamba grass | Conservation Advice. Habitat modification from invasive grasses and changed fire regime due to invasive grasses. |
| *Mesembriomys gouldii melvillensis* | black-footed tree-rat *(Melville Island)* | VU | mission grasses | Conservation Advice. Habitat change due to exotic invasive grasses, change in fire regimes due to exotic grasses. |
| *Notomys aquilo* | northern hopping-mouse | EN | gamba grass | Invasive grasses KTP listing advice; Conservation Advice. Changed fire regime due to invasive grasses. |
| *Phascogale pirata* | northern brush-tailed phascogale | VU | gamba grass, mission grasses | Conservation Advice; Listing Advice. |

| Scientific name | Common name | EPBC Act status | Grass threat (If known) | Notes |
|---|---|---|---|---|
| *Petrogale concinna canescens* | Nabarlek (Top End) | EN | - | Conservation Advice. Invasive pasture grasses may change floristic composition and increase fire intensity. |
| *Sminthopsis butleri* | Butler's dunnart | VU | - | Conservation Advice. Possible threat from exotic pasture grasses that change habitat and fire regimes. |
| *Trichosurus vulpecula arnhemensis* | northern brushtail possum | EN | gamba grass, mission grasses | Conservation Advice; Woinarski et al. (2014). Habitat modification (impairing ground movement) and changed fire regime due to invasive grasses. |
| *Xeromys myoides* | water mouse, false water rat, Yirrkoo | VU | hymenachne, para grass | Draft Recovery plan, Conservation Advice. Invasive grasses modify habitat and increasing fire intensity. |
| *Zyzomys maini* | Arnhem rock-rat | VU | - | TAP (2012). Inappropriate fire regimes. |
| **Fish** | | | | |
| *Chlamydogobius micropterus* | Elizabeth springs goby | EN | hymenachne, para grass | Recovery Plan; Fensham et al. (2010) |
| *Chlamydogobius squamigenus* | Edgbaston goby | VU | hymenachne para grass | Fensham et al. (2010) |
| *Melanotaenia eachamensis* | Lake Eacham rainbowfish | EN | para grass | Listing Advice. Smothering of riparian zones by para grass. |
| *Scaturiginichthys vermeilipinnis* | redfin blue eye | EN | hymenachne, para grass | Fensham et al. (2010) |
| **Reptiles** | | | | |
| *Diplodactylus occultus* | yellow-snouted gecko | EN | mission grasses | KTP listing Advice; Woinarski and Winderlich (2014) |
| *Egernia obiri* | Arnhem Land egernia | EN | gamba grass, mission grasses | Conservation Advice. Potential threat through altered fire regimes. |
| *Lucasium occultum* | yellow-snouted ground gecko | EN | gamba grass, mission grasses | Conservation Advice; PWC NT, 2006. Threatened due to formation of a denser understorey and encouragement of large-scale intense fires. |
| *Phyllurus pinnaclensis* | Pinnacles leaf-tailed gecko | CR | - | Hoskin et al. (2019). invasive grasses prevent regeneration of forest following burning, and changes in fire regime. |
| **Amphibians** | | | | |
| *Uperoleia daviesae* | Howard river toadlet, Davies's toadlet | VU | gamba grass, mission grass | Conservation Advice. Mission and gamba grass may alter |

| Scientific name | Common name | EPBC Act status | Grass threat (If known) | Notes |
|---|---|---|---|---|
| | | | | sandsheet heathland habitat structure. |
| **Invertebrates** | | | | |
| *Euploea alcathoe enastri* | Gove crow butterfly | EN | gamba grass, mission grass | Recovery Plan; Listing Advice |
| *Trisyntopa scatophaga* | antbed parrot moth | EN | gamba grass | Gamba grass is a threat to golden-shouldered parrot, on which the moth is dependent (Cape York NRM 2011) |
| **Plants** | | | | |
| *Acacia praetermissa* | wattle shrub | VU | - | High intensity fire which high biomass grasses may facilitate |
| *Atalaya brevialata* | shrub | CR | gamba grass, mission grasses | Conservation Advice. Potential threat via changes in fire regimes. |
| *Burmannia* sp. Bathurst Island (R.Fensham 1021) | leafless plant  also known as *Burmannia championi* | EN | - | Conservation Advice. Inappropriate fire regimes from invasive grasses. |
| *Calophyllum bicolour* | tree | VU | - | Conservation Advice. Exotic grasses possible threat via inappropriate fire regimes. |
| *Cyathea exilis* | tree fern | EN | gamba grass | Cape York NRM (2011). Competition and high intensity fires. |
| *Clausena excavata* | shrub | CR | gamba grass, mission grasses | Conservation Advice. High intensity fires due to invasive pasture grasses |
| *Dodonaea rupicola* | velvet hopbush | VU | mission grasses | SPRAT |
| *Elaeocarpus miegei* | tree | EN | gamba grass, mission grasses | Conservation Advice. Change in fire regime following grass invasion, and positive feedback |
| *Eleocharis retroflexa* | sedge | VU | hymenachne, para grass | KTP listing advice |
| *Eriocaulon carsonii* | salt pipewort, button grass | EN | hymenachne, para grass | Fensham et al. (2010) |
| *Eryngium fontanum* | blue devil | EN | hymenachne, para grass | Fensham et al. (2010) |
| *Eucalyptus raveretiana* | black ironbox | VU | - | Conservation Advice. Potential threat increased fire frequency from fuel associated with introduced grasses. |
| *Erythroxylum* sp. Cholmondely Creek (J.R.Clarkson 9367) | small shrub | VU | gamba grass, para grass | Conservation Advice. Altered fire regimes from invasive grasses a low threat. |
| *Fimbristylis adjuncta* | sedge | EN | hymenachne | Conservation Advice |

| Scientific name | Common name | EPBC Act status | Grass threat (If known) | Notes |
|---|---|---|---|---|
| *Helicteres macrothrix* previously known as *Helicteres* sp. Glenluckie Creek | shrub | EN | gamba grass, mission grasses | Crowley (2008); Woinarski et al. (2007) Change in fire regime, soil hydrology and nitrogen. |
| *Hibiscus brennanii* | shrub | VU | - | Potential threat, inappropriate fire regimes from invasive grasses. |
| *Hibiscus cravenii* | shrub | VU | - | Potential threat, inappropriate fire regimes from invasive grasses. |
| *Tarennoidea wallichii* | small tree | EN | gamba grass mission grasses | Conservation Advice and NT DEPWS 2021. Invasive grasses change fire regimes, community structure, soil chemistry. Also interactive impacts of hydrological and land system modification. |
| *Typhonium jonesii* | herb | EN | gamba grass, mission grasses | Conservation advice |
| *Typhonium mirabile* | herb | EN | gamba grass, mission grasses | Conservation Advice |
| *Typhonium taylori* | small arum lily-like plant | EN | para grass | Crowley (2008) |
| *Xylopia monosperma* | shrub | EN | gamba grass, mission grasses | Listing Advice |

**Table A2 Ecological communities threatened by invasive grasses, and World Heritage sites, National Heritage places and Ramsar wetlands where these grasses are present and are a known or potential threat to the ecological character.**

| Ecological community or area | Listing/ declaration | Grass threat | Notes |
|---|---|---|---|
| Arnhem Plateau sandstone shrubland complex | Endangered ecological community | gamba grass, mission grasses | Listing advice. Invasive grasses, and grass fire cycle a potential threat (Rossiter et al. 2003) |
| The community of native species dependent on natural discharge of groundwater from the Great Artesian Basin | Endangered ecological community | hymenachne, para grass | Fensham et al. (2010); SPRAT |
| Bowling Green Bay | Ramsar wetland | hymenachne, para grass | DES (2013) |
| Cobourg Peninsula | Ramsar wetland | Hymenachne, para grass | CRC Weed Management (2003). Para grass noted as potential threat in Ecological Character Description |
| Kakadu National Park | Ramsar wetland | gamba grass, hymenachne, para grass | BMT WBM (2010). This includes the Alligator River system and the top of the Mary River catchment |
| Kakadu National Park | World Heritage | gamba grass, mission grass, para grass, hymenachne | All species within this plan are present in Kakadu NP |
| Lakes Argyle and Kununurra | Ramsar wetland | mission grass | Present in riparian areas (Hale and Morgan 2010) |
| Nardab floodplain | Ramsar wetland, partly within Kakadu National Park | para grass | - |
| Ngarrabullgan (Mount Mulligan) | National Heritage | gamba grass | - |
| Roebuck Bay | Ramsar wetland | para grass, mission grass | Para grass and mission grass noted as potential threat in Ecological Character Description |
| Shoalwater and Corio Bays | Ramsar wetland | hymenachne, para grass | DES (2013a) |
| Wet Tropics of Queensland | World Heritage | gamba grass, hymenachne, para grass | WTMA (2007) |

**Table A3 Species listed under state or territory legislation (NSW, *Biodiversity Conservation Act 2016*; NT, *Territory Parks and Wildlife Conservation Act 1976*; Qld *Nature Conservation Act 1992*) that are known or considered to be threatened by one or more of the invasive grasses. Many of these species are threatened due to the altered fire regimes these grasses create.**

| Species | Common name | Listing in NSW, NT, or Qld | Grass threats | Notes |
|---|---|---|---|---|
| **Animals** | | | | |
| *Anseranas semipalmata* | Magpie goose | NSW Vulnerable | hymenachne, para grass | SPRAT; Setterfield et al. (2013) |
| *Attacus wardi* | Atlas moth | NT Vulnerable | gamba grass, mission grasses | NT Gov (2021). Exotic grass invasion causing inappropriate fire regimes |
| *Ogyris iphis doddi* | Dodd's azure | NT Endangered | gamba grass, mission grasses | High intensity fires due to perennial pasture grasses. |
| *Phyllurus pinnaclensis* | Pinnacles leaf-tailed gecko | Queensland Critically Endangered | - | Hoskin et al. (2019). invasive grasses prevent regeneration of forest following burning, and changes in fire regime. |
| *Rattus tunneyi* | Pale field rat | NT Vulnerable | gamba grass, grass mission grasses | Woinarski and Winderlich (2014). Possible threat via higher intensity fires. |
| *Setobaudinia victoriana* | Victoria's land snail | NT Vulnerable | gamba grass, mission grasses | Increased intensity and frequency of fire, promoted by exotic pasture grasses, and livestock grazing of exotic grasses. |
| **Plants** | | | | |
| *Arivela insolata* | A herb | NT Vulnerable | gamba grass, mission grasses | High intensity fires due to invasive pasture grasses |
| *Cycas armstrongii* | A cycad | NT Vulnerable | gamba grass, mission grasses | Woinarski and Winderlich (2014). Invasive pasture grasses serious threat due to increase fire severity. |
| *Cycas semota* | A cycad | Qld Endangered | gamba grass | Cape York NRM (2011) |
| *Dienia montana* | orchid | NT Vulnerable | - | Woinarski and Winderlich (2014). Invasive pasture grasses at rainforest margin may increase risk of fire impacts. |
| *Jacksonia divisa* | A shrub | NT Vulnerable | - | Invasive grasses a possible threat through changed fire regimes. |
| *Luisia teretifolia* | Luisia orchid | NT Vulnerable | gamba grass, mission grasses | Crowley (2008). High fire intensity fires fuelled by introduced grasses. |
| *Crepidium marsupichilum* | ground orchid | NT Vulnerable | gamba grass, mission grasses | Crowley (2008). High fire intensity fires fuelled by introduced grasses |

| Species | Common name | Listing in NSW, NT, or Qld | Grass threats | Notes |
|---|---|---|---|---|
| (Previously *Malaxis marsupichilal*) | | | | |
| *Monochoria hastata* | Arrowleaf monochoria<br><br>Aquatic herb | NT Vulnerable | para grass, hymenachne | Woinarski et al. (2007) |
| *Ptychosperma macarthurii* | Darwin palm | NT Endangered | gamba grass, mission grasses | Changes in fire regime |
| *Pterostylis caligna* | greenhood orchid | Qld Endangered | gamba grass | Mathieson (2013) |
| *Schoutenia ovata* | Yellow star<br><br>A shrub or tree | NT Endangered | gamba grass, mission grasses | Possibly threatened by changed fire regime, soil hydrology and nitrogen availability due to grass invasion. |
| *Typhonium praetermissum* | perennial geophyte (predominately subterranean herb) | NT Vulnerable | gamba grass, mission grasses | Reduced habit quality, and changes in fire regime |
| *Utricularia dunstaniae* | bladderwort | NT Vulnerable | para grass | Crowley (2008) Changes in fire regime. |
| *Utricularia singeriana* | bladderwort | NT Vulnerable | para grass | Crowley (2008) Changes in fire regime. |
| *Zeuxine oblonga* | ground orchid | NT Vulnerable | gamba grass, mission grasses | Crowley (2008). High fire intensity fires fuelled by introduced grasses. |

**Table A4 Indigenous ecological knowledge of native species threatened by invasive grasses. This information was obtained through interviews and surveys conducted by Territory Natural Resource Management in 2022. This information is geographically limited, as the interviews and surveys were predominately with First Nations people based in the NT, with a smaller subset taking part from Queensland and WA (see section 5 of the Background document).**

| Native species | English Common Name | Invasive grass species posing threat (if identified) |
|---|---|---|
| *Acacia shirleyi* | lancewood | - |
| *Cacatua galerita* | sulphur-crested cockatoo | gamba grass |
| *Callitris columellaris* | blue cypress pine | - |
| *Carlia gracilis* | slender rainbow skink | para grass |
| *Carlia munda* | striped rainbow skink | gamba grass |
| *Cracticus nigrogularis* | pied butcherbird | gamba grass |
| *Carlia rufilatus red-sided* | red-sided rainbow skink | gamba grass |
| *Ctenotus robustus* | robust ctenotus | para grass |
| *Cryptoblepharus plagiocephalus* | arboreal snake-eyed skink | gamba grass |
| *Ctenotus essingtonii* | Port Essington ctenotus | gamba grass |
| *Ctenotus storri* | Storr's ctenotus | gamba grass |
| *Dacelo leachii* | blue-winged kookaburra | gamba grass |
| *Diporiphora Bilineata* | two-lined dragon | gamba grass |
| *Entomyzon cyanotis* | blue-faced honey-eater | gamba grass |
| *Geophaps scripta* | squatter pigeon | - |
| *Geophaps smithii* | partridge pigeon | - |
| *Heteronotia binoei* | Bynoe's gecko | gamba grass |
| *Menetia alanae* | Alan's menetia | gamba grass |
| *Poephila personata* | masked finch | - |
| *Poephila acuticauda* | long-tailed finch | - |
| *Poephila cincta* | black-throated finch | - |
| *Psephotus dissimilis* | hooded parrot | - |
| *Trichoglossuc haematodus* | rainbow lorikeet | gamba grass |

**Table A5 Other native non-threatened species known to be impacted by one or more of the invasive grass species.**

| Species | Common name | Grass threat | Reference |
|---|---|---|---|
| *Acacia shirleyi* | lancewood | gamba grass, mission grasses | KTP listing advice |
| *Aponogeton cuneatus* | aquatic perennial plant with a tuber | hymenachne | Cape York NRM (2011) |
| *Aponogeton queenslandicus* | aquatic perennial plant with a tuber | hymenachne | Cape York NRM 2011) |
| *Callitris columellaris* | blue cypress pine | gamba grass, mission grasses | KTP listing advice |
| *Chelodina rugosa* | northern snake-necked turtle | para grass | Hannan-Jones and Csurhes (2012); Walden & Bayliss (2003) |
| *Climacteris picumnus melanotus* | brown treecreeper (Cape York peninsula) | gamba grass | Cape York NRM (2011). Grass fire cycle |
| *Didymuria virginea* | Cape York stick-insect | gamba grass | IUCN red list: data deficient |
| *Eleocharis dulcis* | annual native water chestnut | para grass | Ferdinands et al. (2005) |
| *Elseya irwini* | Johnstone River snapping turtle | para grass | QLD Gov (2017) |
| *Lates calcarifer* | barramundi | para grass | Hyland (2002) |
| *Melaleuca cajuputi* | melaleuca | para grass | Ferdinands et al. (2005) |
| *Nettapus coromandelianus albipennis* | Australian cotton pygmy-goose | hymenachne | SPRAT |
| *Oryza meridionalis* | native wild rice | para grass | Ferdinands et al. (2005) |
| *Oryza rufipogon* | native wild rice | para grass | Walden & Bayliss (2003) |
| *Rattus colleti* | dusky plains rat | para grass | Walden & Bayliss (2003) |
| - | Coastal grass-sedge wetlands in Qld<br><br>There are 10 Qld regional ecosystems containing coastal grass-sedge wetlands of conservation significance | para grass, hymenachne | See QLD EPA (2006) for the full list of wetland communities potentially impacted |

# Appendix B. Relevant actions from the Kakadu National Park Management plan 2016-2026

**Wetlands**

5.2.3 Manage weeds on the floodplains, prioritising control of ecosystem-transforming weeds (including para grass and olive hymenachne) in priority areas and continued eradication of mimosa.

5.2.5 Manage fire on the floodplains in accordance with the Policies and Actions in Sections 5.3.17 to 5.3.26 to:

   a)  replicate the traditional floodplain burning regime

   b)  reduce cover of Hymenachne, para grass and other floodplain weed species and promote Eleocharis and other native wetland plant species

**Low land plains**

5.2.10 Manage fire in the lowlands in accordance with the Policies and Actions in Sections 5.3.17 to 5.3.26 to reduce impact on plants, animals and habitats.

5.2.11 Manage weeds in the lowlands prioritising control of the spread of gamba grass.

**Rainforest**

5.2.16 Manage weeds in and adjacent to priority rainforest patches, prioritising control of species that are contributing to increased intensity of fire on rainforest margins (e.g. para grass).

**Weeds in general**

5.3.4 Implement, review and update a park weed management strategy to minimise the impacts of weeds on the park's values through:

   a)  assessing risks to park values posed by current and potential weeds

   b)  prioritising control of invasive species, giving priority to controlling species that pose a high risk of threatening ecosystem function and/or priority areas, and/or are feasible to control, taking into account changing climatic conditions

   c)  using a range of efficient and cost-effective mechanisms to deliver weed management and control. This may include the introduction of non-native biological control agents where they are likely to pose low or no risk to park values

   d)  monitoring invasive species spread and effectiveness of control works

   e)  awareness of potential new weed species and proposing measures to prevent and/or manage them

   f)  adjusting control strategies in response to an improved understanding of invasive species and control methods.

5.3.5 Develop and implement a weed education programme for park residents, staff, contractors, tour operators and visitors – including how to recognise weeds and their impacts, and information on transfer by vehicles, trailers and vessels and the regulations regarding the entry of plant, animal and soil material into the park.

5.3.6 Provide training opportunities on weed identification, control and monitoring for park staff, Bininj/Mungguy, neighbouring Indigenous ranger groups and other stakeholders involved in weed management.

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