

## Supplementary Material

### Unassisted invasions: understanding and responding to Australia's high-impact environmental grass weeds

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#### Table S1. High-impact environmental species, the evidence used to assess them against the criteria for high-impact species, and key aspects of their biology.

Evidence for tropical species was provided elsewhere (van Klinken *et al.* 2013) but is repeated here. To generate the list of high-impact temperate species we first took environmental weeds previously categorised (Groves 2003) as four or five in severity, on a scale of one to five, but excluding "primarily agricultural or ruderal weeds", and the full list of species considered for the Weeds of National Significance prioritisation process (Thorp and Lynch 2000). These were then assessed against impact criteria to generate the short-list by iterative reduction against our criteria through:

- searching the Web of Science (using species names, main synonyms and widely used common names),
- broader web-based searches of grey literature and databases, including specific resources such as Lucid and Aussiegrass2), and
- consulting a wide range of temperate weed experts and through a list-server discussion group on environmental weeds in Australia (aliens-l listserver). This also provided additional grey literature.

For most species experts were required to provide specific examples against criteria as no unambiguous published data could be found.

The criteria for high environmental impact (van Klinken *et al.* 2013) were that species:

- had become dominant (defined as percent herbaceous cover),
- were on land managed for environmental values,
- occurred as the result of natural spread (implying an ability to invade), and
- were not dependent on human related disturbance (e.g. excludes roadsides that are regularly slashed, high-use areas such as campgrounds, and land that has historically had heavy, prolonged grazing).

Dominance was used as a surrogate of impact as environmental impact of most alien grass species has not been quantified. Specific examples where all criteria were met were required for a species to be considered as high-impact.

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Species	Common name	Region	Habitat	Life History	Evidence against criteria
<i>Ammophila arenaria</i> (L.) Link	Marram grass	Temperate	Terrestrial	Perennial	Invades and becomes dominant on many Tasmanian beaches, up to 110 km from deliberate plantings. Remains dominant under regularly (naturally) disturbed sands, can displace several coastal dune plant communities (Rosengren 1978, Tasmania Parks Service 2003).
<i>Andropogon gayanus</i> Kunth	Gamba grass	Tropical	Terrestrial	Perennial	Can become dominant in diverse savanna communities under relatively natural disturbance regimes: it does not require soil or canopy disturbance to become established (van Klinken <i>et al.</i> 2013).
<i>Anthoxanthum odoratum</i> L.	Sweet vernal grass	Temperate	Terrestrial	Perennial	Invades undisturbed, natural montane and subalpine grasslands in the Snowy Mountains of New South Wales (Pickering and Hill 2007). Reaches dominance without the assistance of human-disturbance within the Victorian Alpine National Park (montane to high subalpine), preventing native species recovery (Cheal, pers. comm. November 2016).
<i>Cenchrus ciliaris</i> L.	Buffel grass	Tropical	Terrestrial	Perennial	Becomes dominant and forms near monocultures across rangeland Australia, including in ungrazed environmental reserves (van Klinken <i>et al.</i> 2013).
<i>Cenchrus pedicellatus</i> (Trin.) Morrone	Annual mission grass	Tropical	Terrestrial	Annual/perennial	Behaves similarly to <i>C. polystachios</i> . "It has demonstrated its capacity to invade and become prominent in intact native vegetation at numerous sites in the Darwin region. Examples included Cycad study sites (Charles Darwin National Park), Litchfield National Park and open woodland in the Blackmore river area subject to background natural disturbance

					(occasional fire and native herbivores)" (van Klinken <i>et al.</i> 2013).
<i>Cenchrus polystachios</i> (L.) Morrone	Perennial mission grass	Tropical	Terrestrial	Annual/perennial	Invades natural bushland where it displaces native plants, resulting in continuous cover beneath an intact canopy. More widespread than <i>Andropogon gayanus</i> , and reaches very high density and biomass in environmental reserves including Litchfield National Park, Northern Territory. Prevalence on environmental reserves high despite ongoing control efforts. Listed as one of the species in (Australian Government: Department of the Environment and Energy 2012).
<i>Cenchrus setigerus</i> Vahl	Birdwood grass	Tropical	Terrestrial	Perennial	Behaves similarly to <i>C. ciliaris</i> in the Pilbara Region of Western Australia (van Klinken <i>et al.</i> 2013).
<i>Echinochloa polystachya</i> (Kunth) Hitchc.	Aleman grass	Tropical	Semi-aquatic	Perennial	Dry tropics and coastal north Queensland. Potential to form mono-specific stands in seasonally wet and dry areas such as flood plains and swamps where it will smother native species. Invades seasonally flooded areas, swamps and banks of watercourses in Queensland. Has become dominant in wetlands above the Barrage (Fitzroy River) under relatively natural (ungrazed) disturbance regimes (van Klinken <i>et al.</i> 2013).
<i>Ehrharta calycina</i> Sm.	Perennial veldtgrass	Temperate	Terrestrial	Perennial	Becomes dominant in understory of banksia woodlands in southwest Western Australia, competing strongly with native shrubs and, in extreme cases, reducing the banksia and eucalypt overstorey. Invasion does not need gross disturbance in

					Karrkatta and Transitional soils (Bridgewater and Backshall 1981).
<i>Eragrostis curvula</i> (Schrad.) Nees	African love grass	Tropical	Terrestrial	Perennial	Becomes dominant in Travelling Stock Reserves (including New England peppermint woodlands) and road reserves of New South Wales, possibly also fits criteria locally in National Parks, especially granite country of the northern Tablelands of New South Wales. Can become dominant in absence of heavy grazing in very poor country where herbaceous cover is naturally low under trees (van Klinken <i>et al.</i> 2013).
<i>Hymenachne amplexicaulis</i> (Rudge) Nees	Olive hymenachne	Tropical	Semi-aquatic	Perennial	Extensively invades native wetlands where it forms monocultures under relatively natural disturbance regimes. One of the species cited in (Australian Government: Department of the Environment and Energy 2012).
<i>Hyparrhenia hirta</i> (L.) Stapf	Tambookie grass; coolatai grass	Tropical	Terrestrial	Perennial	Becomes dominant in woodlands of Kwiambul National Park, on the northwest slopes of New South Wales. This National Park was grazed prior to purchase as an environmental reserve in 1995, but <i>H. hirta</i> continues to spread and increase in the park under relatively natural disturbance regimes. Becomes dominant in roadside reserves and Travelling Stock Routes and native pastures, including where disturbance regimes are relatively natural. However, we could find no record of dominance in parks/reserves that had not previously been pastoral. In northern Queensland it is becoming dominant under relatively natural disturbance regimes (although on extensive pastoral properties),

					but there are questions about its taxonomy there (van Klinken <i>et al.</i> 2013).
<i>Megathyrsus maximus</i> (Jacq.) B.K.Simon & S.W.L.Jacobs	Guinea grass	Tropical	Terrestrial	Perennial	42 km of Hervey Bay, Queensland, foreshore invaded, of which more than half is heavily invaded; invades dry rainforest and undisturbed areas in northern New South Wales; major weed in riparian areas in northern Queensland where it has replaced <i>Sorghum nitida</i> , especially in wetter areas. Maintains monospecific stands along sandy seashores of Mackay, Queensland. However, most commonly associated with high anthropogenic disturbance such as along roadside and forest margins (van Klinken <i>et al.</i> 2013).
<i>Melinis minutiflora</i> P.Beauv.	Molasses grass	Tropical	Terrestrial	Perennial	Forms dense monocultures in relatively undisturbed dry sclerophyll forests in southeast Queensland, rapid coloniser of severely burnt sites (such as the foothills around Cairns, northern Queensland). Is driving forest edges back, and forms monocultures in State Forests on Queensland's Gillies Ranges under relatively natural disturbance regimes, often in mesic places around granite boulder fields. However, most commonly associated with high anthropogenic disturbance such as along roadside and forest margins (van Klinken <i>et al.</i> 2013).
<i>Spartina anglica</i> C.E.Hubb	Common cordgrass; rice grass	Temperate	Aquatic	Perennial	Invades and becomes dominant in mudflats without assistance of anthropogenic disturbance, including in remote parts of the Tamar Estuary in northern Tasmania (Ellison and Sheehan 2014; Sheehan and Ellison 2014).

<i>Themeda quadrivalvis</i> (L.) Kuntze	Grader grass	Tropical	Terrestrial	Annual	In Lakefield National Park, northern Queensland, it is replacing and dominating savanna grasslands including native perennial grasses under relatively natural disturbance regimes where soil types are favourable. However, gaining dominance most commonly requires bare ground resulting from heavy cattle grazing or poor fire management regimes (van Klinken <i>et al.</i> 2013).
<i>Urochloa mutica</i> (Forssk.) T.Q.Nguyen	Para grass	Tropical	Semi-aquatic	Perennial	Invades and dominates extensive wetlands in the Northern Territory. This includes extensive monocultures in the Magela Creek Floodplain on Kakadu National Park which are continuing to expand under relatively natural disturbance regimes. It is "quickly filling in a number of Kakadu's wetlands" (van Klinken <i>et al.</i> 2013).

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