Buffel grass (*Cenchrus ciliaris* L.): presenting the arid Northern Territory experience to our South Australian neighbours

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Introduction

Buffel grass (*Cenchrus ciliaris* L.) is a perennial tussock grass native to Africa, India and Asia with a wide naturalized distribution in Australia (Butler and Fairfax 2003). In arid Northern Territory (NT) it has spread widely from introduction points and now occurs extensively across all land tenures. In the early years of establishment, *C. ciliaris* was generally viewed in the region as a desirable species for land rehabilitation and pastoralism. However, in recent years there has been growing concern of its impacts on biodiversity. In this paper we examine some of the issues associated with the proliferation of *C. ciliaris* in arid NT, particularly from a conservation perspective.

Taxonomy

Cenchrus ciliaris L. is a morphologically variable species in arid NT, with plants differing in features such as height, rhizome development, leaf colour, ligule length, inflorescence length and width, burr colour and the degree to which the burr bristles are fused at the base. The NT Herbarium currently recognizes buffel grass as one variable species, *C. ciliaris*. However, there may be merit following Sharp and Simon (2002) in distinguishing a segregate species, *C. pennisetiformis* Hochst. & Steud. on the basis of greater fusion length in the burr bristles. Even if *C. pennisetiformis* is recognized, there remains considerable variation within *C. ciliaris*. Some morphologically distinct forms of *C. ciliaris* occur in arid NT, some of which even have an ecological basis; however the taxonomy is not being studied and we are still a long way from being able to apply cultivar names with certainty. It has been possible to trace the cultivar names of deliberate introductions from some old seed purchase records. However in some cases plants grown from seed lots do not match descriptions of their assigned cultivar and consequently introduction records may not be reliable indicators of taxonomic status. Paull and Lee (1978) have recorded hybridization in *C. ciliaris* elsewhere but the likelihood or extent of this in arid NT is unknown.

Biological attributes that contribute to the success of *C. ciliaris*

Cenchrus ciliaris has a range of biological features that enable it to be a highly competitive species in arid NT. It is relatively drought tolerant, fire resistant, can withstand heavy grazing, responds quickly to rain, and establishes self sustaining populations in a wide range of habitats (Batra and Kumar 2003). It also has a rapid growth rate, fast maturation, prolonged flowering/fruiting periods, prolific seed production, high seed dispersal ability and long seed dormancy (Franks *et al.* 2000). *C. ciliaris* is a C4 species and gains biomass and recruits most vigorously with rains during the warmer months of the year. In frost-prone areas of arid NT the species effectively becomes dormant during winter once the leaves are cured by frost.

History of introduction

Cenchrus ciliaris seed was unintentionally introduced to central Australia during the 1870s in pack saddle stuffing used by Afghan cameleers (Humphries 1967). Since the 1950s it has been deliberately introduced in arid NT by Government agencies, non-government groups and individuals for pasture improvement and soil stabilization. Several cultivars have been sown in arid NT by NT Government agencies up until the 1980s, with intensive sowings near the Alice Springs township and on various stations and Aboriginal communities for dust suppression purposes. For example, 1200 ha of *C. ciliaris* was sown annually from 1972 to 1978 as part of the Alice Springs Dust Control project (Keetch 1979). Up until the mid 1970s Parks and Wildlife were planting *C. ciliaris* on the reserve estate in arid NT for erosion control purposes (Albrecht and Pitts 1997). NT Government departments no longer sow *C. ciliaris* due to concerns about its invasiveness and potential impacts on biodiversity. However, the species continues to be intentionally spread on some pastoral stations.

Patterns of spread

Cenchrus ciliaris burrs contain 1–3 seeds and are covered with barbellate bristles, which enable them to attach to clothing and animal fur. Dispersal units are also spread by vehicles and by wind and water. Although there is yet to be a systematic investigation of the invasion process in arid NT, anecdotal evidence suggests that burrs or seeds are often dispersed along roads or tracks from an initial introduction point, and then dispersed into roadside vegetation by wind and water with drainage lines acting as conduits for more distant dispersal. Plants commonly establish beneath trees and shrubs and infilling occurs during periods of significant rainfall. Periods of exceptional summer rainfall such as occurred in the early 1970s and again in the early 2000s have been particularly significant in the expansion of *C. ciliaris* in arid NT.

Distribution – current and potential

Cenchrus ciliaris now occurs in all mainland states of Australia (Best 1998). It is estimated to cover between 30 and 50 million hectares in Queensland alone (Hannah and Thurgate 2001), but no such estimate is available for arid NT. Figure 1 shows the point locations for *C. ciliaris* recorded in the Northern Territory, although the species actual distribution is likely to be much greater. It occurs in a range of habitats in arid NT but appears to invade and dominate certain environments more rapidly, particularly sites with fertile (predominantly alluvial plains, watercourses and run-on areas but also certain areas of undulating to mountainous terrain with shallow soils) and/or basic (derived for example from dolomite, limestone or calcrete) soils. *C. ciliaris* occurs on much of the fertile alluvial country in arid NT with the exception of very remote areas, but has not invaded such a high proportion of the available fertile hills and ranges. Habitats that appear to be less susceptible to invasion at present include areas with deep infertile sands dominated by *Triodia* spp. (e.g. Simpson, Great Sandy and Tanami Deserts), red earth plains dominated by Mulga (*Acacia aneura* F.Muell. ex Benth.), salt lakes and cracking clay plains (e.g. Barkly Tableland). It is uncertain to what extent *C. ciliaris* will invade these habitats. There is some indication that *C. ciliaris* may be able to invade deep infertile sandy soils when Desert Oak (*Allocasuarina decaisneana* (F.Muell.) L.A.S.Johnson) is present because soil pH is elevated beneath the tree canopy. Intensified disturbance regimes, the introduction of new cultivars, and local adaptation are factors that may enable *C. ciliaris* to invade new habitats.

Pastoral interest

Cenchrus ciliaris has growth response characteristics that enable it to withstand persistent heavy grazing and increase stock carrying capacity (Humphreys and Partridge 1995, Allan 1997). For these reasons it continues to be actively planted

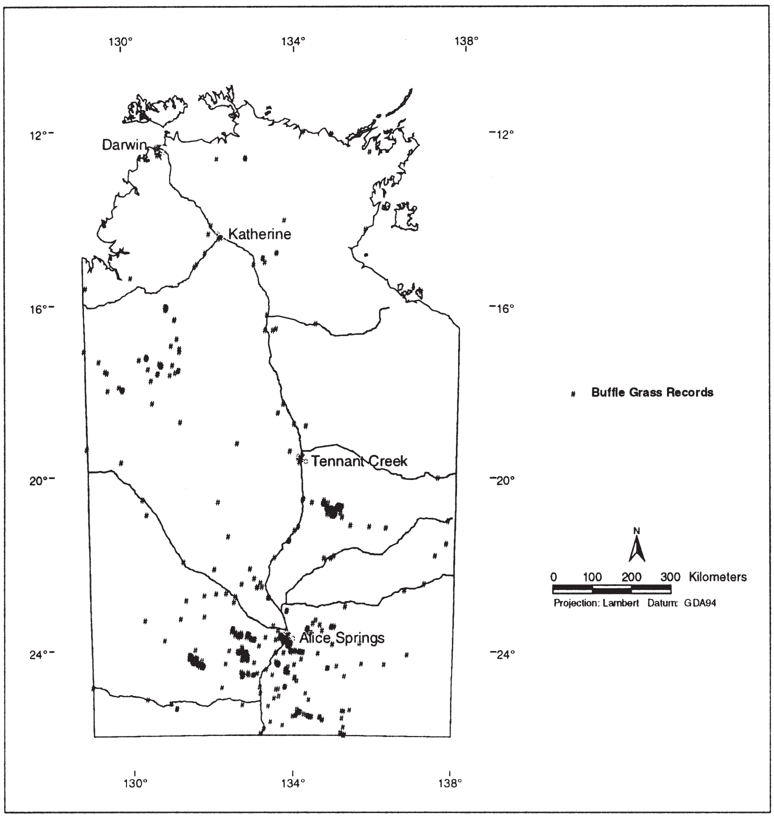

Figure 1. Point location records for *Cenchrus ciliaris* in the Northern Territory (based on data from Northern Territory Herbarium and Australian Virtual Herbarium voucher specimens, Biophysical mapping, Land Unit mapping, Bioregion surveys and Park weed control points).

on some pastoral properties in arid NT. In Queensland, *C. ciliaris* has brought financial benefit to many individual producers and companies as well as support to rural communities due to its benefit to the pastoral industry (Hall 2000). The spread of *C. ciliaris* onto non-pastoral land has considerable 'hidden' costs associated with it. Approximately $170 000 is spent annually on *C. ciliaris* control work in conservation reserves in arid NT which is still only a fraction of what would be required to remove *C. ciliaris* from all areas where its presence is conflicting with conservation management. Other 'hidden' costs include works associated with fire mitigation on various tenures, and the potential impact on the aesthetic landscape of arid NT for the tourist industry.

Cenchrus ciliaris is likely to be of greatest value to pastoralists in arid NT when it occurs sparsely amongst a range of native species, principally because native species fatten cattle and *C. ciliaris* provides feed when native feed is scarce (P. Latz personal communication). Although highly palatable to grazing animals, *C. ciliaris* has a substantially high lignin content that reduces its digestibility (Minson and Bray 1986) and cattle have been observed to preferentially graze native forbs and grasses before selecting *C. ciliaris* in the same pasture.

Cenchrus ciliaris will gain dominance on sites with reasonable soil fertility. Once its density surpasses a certain threshold a large range of short lived native grasses and forbs that are important in fattening cattle are competitively excluded. *C. ciliaris* has a high demand for available soil nitrogen and phosphorus and as *C. ciliaris* assumes dominance, soil nitrogen is depleted and growth begins to decline in what has been described as a 'run-down' effect with an associated decline in cattle live-weight gain (Cavaye 1991). Furthermore, due to the dominance of asexual seed formation in *C. ciliaris*, populations of a cultivar tend to have little genetic variability rendering them susceptible to local epidemics. This scenario has been experienced in Queensland with the spread of a blight caused by *Pyricularia grisea* (Perrot and Chakraborty 1999, Rodriguez *et al.* 1999) and more recently *Fusarium oxysporum* (Makiela *et al.* 2003). Hence, there is significant risk associated with a dependency on *C. ciliaris*, especially where it becomes so dominant that other native grass species are lost from the system. Hall (2000) reports a developing reluctance by some producers with good native pastures to plant *C. ciliaris* due to these problems in longer-term production viability.

Conservation concerns

Cenchrus ciliaris is now perceived as a major threat on conservation lands in arid NT because of its ability to modify vegetation structure and reduce species diversity (Albrecht and Pitts 1997). Potential threats include increased competition with native vegetation for nutrients, water and light, allelopathic alteration of soil properties that inhibit germination and growth of other plants, alteration of ecosystem processes such as fire regime and succession, and displacement of native animals through changes to habitat structure and composition (Cheam 1984, Best 1998, Butler and Fairfax 2003, Miller 2003). *C. ciliaris* establishment in the very restricted habitats of the shaded cliffs and gorges in arid NT brings it into direct competition with many of the regions' rare and relict plant species (Griffin 1993). Central Australian vegetation has adapted to extremely unpredictable rainfall. Recruitment, vegetative growth and flowering of many plant species are generally associated with periods of higher rainfall. If rapid growth of *C. ciliaris* results in fires at times outside of these major pluvial periods, native plant mortality may be greater because plants are already stressed, and the likelihood of subsequent germination reduced (Miller 2003). Few published studies have directly measured the impacts of *C. ciliaris* in arid NT though many have reported potential threats.

Research on impacts of *C. ciliaris* beyond arid NT

Much of the published research on impacts of *C. ciliaris* in arid environments has been carried out in central Queensland. Ludwig *et al.* (2000) found that numbers of Carnaby's skink (*Cryptoblephrus carnabyi*) and delicate mouse (*Pseudomys delicatulus*) declined as the cover of *C. ciliaris* increased in eucalypt woodlands. The number of native ground cover species has been shown to decline significantly with an increase in the cover of *C. ciliaris* (Franks 2002). *C. ciliaris* cover has been shown to increase two-fold after fire relative to unburnt patches, consistent with the facilitation of a positive feedback between *C. ciliaris* and fire (Butler and Fairfax 2003). The research on the effects of *C. ciliaris* in central Queensland has generally been carried out in highly modified environments, thereby reducing the applicability of the results to the landscape of arid NT.

Research on impacts of *C. ciliaris* grass in arid NT

There are fewer published accounts of the impacts of *C. ciliaris* in arid NT, however several valuable studies have been undertaken. A long-term study at Simpsons Gap near Alice Springs monitored vegetation change in several vegetation communities over 25 years, from a time prior to *C. ciliaris* invasion through to the establishment of dense stands (P. Latz personal communication). This study showed that there was a significant negative correlation between the abundance of *C. ciliaris* and the abundance of all herbaceous and semi-woody native plant life-form groups. Short-term studies on *C. ciliaris* removal in southern ironwood (*Acacia estrophiolata* F.Muell.) woodland at the Alice Springs Desert Park (ASDP) and in the Ilparpa Valley, near Alice Springs, showed a significantly higher number of native herbaceous and semi-woody plant species in plots that were maintained free of *C. ciliaris* than in control plots. Although of short duration, the later study spanned the exceptionally wet period in the early 2000s, and showed that very little germination of native species occurred in plots with dense *C. ciliaris* (Albrecht unpublished data).

Substantial field evidence supporting the existence of a *C. ciliaris*-initiated positive fire-invasion feedback has been found in a study of burnt woodland areas near Alice Springs (Miller 2003). *C. ciliaris* invasion was significantly correlated with increased fuel loads and increased burn severity, and higher burn severity resulted in greater mortality of woodland overstorey trees (Miller 2003). Best (1998) studied the effects of *C. ciliaris* invasion on invertebrates in the Alice Springs region and found that the total number of species present was significantly reduced, and a majority of invertebrate groups showed lower abundance with *C. ciliaris* presence.

Research on control in arid NT

The bulk of research on *C. ciliaris* in arid NT comes from unpublished studies of control methods. Trials at the ASDP and in the Ilparpa Valley have been carried out to test individually, or in combination, different small scale control techniques including herbicide spraying, hand chipping, burning and slashing. The Ilparpa Valley trials showed that *C. ciliaris* seedling recruitment was relatively equal across all treatments following the first significant rainfall event after treatment, but that in the longer term there was much reduced *C. ciliaris* seedling recruitment on burnt sites than all other treatment types (Albrecht *unpublished data*). This indicates that high fire temperatures may decrease the amount of viable seed in the soil.

Oven trials undertaken as an adjunct to the field burn trials indicate that 200°C for beyond three minutes is the optimal temperature and duration required to kill *C. ciliaris* seed. At lower temperatures such as 100°C, the length of the exposure required increased up to 10 minutes (Albrecht *unpublished data*). Rangers at Finke Gorge National Park have been manipulating the temperature and duration of burns by using spinifex (*Triodia* spp.), a readily available fuel, which is piled on top of small patches of *C. ciliaris* – a technique known locally as deep burning. They have found that 10 minute burns at about 400°C kill *C. ciliaris* seed to a soil depth of 1–2 cm with no *C. ciliaris* regrowth or germination for two to seven years (Dennis Matthews personal communication), which is well past the seed longevity measured for *C. ciliaris* in arid NT (Winkworth 1971). Clearly these deep burns are killing all of the *C. ciliaris* seed within the soil.

Rangers at Finke Gorge NP have been trialing various residual herbicides on small isolated patches of *C. ciliaris*. The most effective of these resulted in no seedling recruitment or post-treatment regrowth of *C. ciliaris* in a period of 14 months after rainfall activation of the herbicide. Resources that would be otherwise spent on *C. ciliaris* follow-up control and monitoring could be reduced if small isolated patches (usually less than 2 × 2 m) can be treated with a residual herbicide.

Directions for future research in arid NT

Under the new Desert Knowledge Cooperative Research Centre, a collaborative project on *C. ciliaris* has been established between CSIRO, James Cook University, NT Parks and Wildlife and the Threatened Species Network. The overall goal of the project is to provide land managers and policy makers with reliable information and the tools required to maximize any benefits associated with *C. ciliaris* whilst minimizing the costs. The project has three main objectives: (i) to identify the impacts of *C. ciliaris* on biodiversity (particularly small reptiles, birds, invertebrates and herbaceous vegetation) in habitats that have not been studied in the Alice Springs area; (ii) to identify *C. ciliaris* dispersal patterns and mechanisms in different cultivars and potential hybrids, and; (iii) to evaluate the use of aerial survey as a method for early detection and mapping of *C. ciliaris* invasion in areas of high conservation value. The project will use traditional techniques of manipulative and observational ecological investigation in parallel with newer landscape genetics techniques.

Management options

In an attempt to present a balanced view of *C. ciliaris* management in arid NT there should be some discussion on how best to manage *C. ciliaris* in a pastoral setting. However, aspects of this are well documented in the literature (Bryant 1961, Millington and Squires 1980, Barker and Kidar 1989, Cavaye 1991, Cook 2000). The following discussion therefore focuses on the control of *C. ciliaris* in areas managed primarily for conservation.

Cenchrus ciliaris occurs in virtually all Parks and Wildlife reserves in arid NT (Albrecht and Pitts 1997) and it dominates the ground layer of vegetation in some Parks. The extent of *C. ciliaris* in arid NT precludes absolute control, so effort is concentrated on priority areas nominated for their biodiversity value in combination with reinvasion potential, accessibility and visitation intensity. Park vegetation mapping has enabled the systematic identification of high biodiversity value areas using a purpose built program that summarizes vegetation attributes including rarity and species richness. Park Rangers have undertaken various management measures including herbicides, herbicides in combination with managed fire, residual herbicides, hand removal, and 'deep burning' with prolonged periods of intense heat. Most of the available techniques to control *C. ciliaris* are effective if undertaken and followed-up at the correct time. Timing is the critical element as resprouting plants can flower within a week of rain and new germinants can grow and set seed in as little as three to four weeks with sufficient moisture.

Generally the most efficient means of control at sites that have a well developed *C. ciliaris* seed bank is to spray plants with herbicide, then burn the dry plant matter and surface seed bed and follow-up spray any regrowth. This method is not applicable to all situations. It is most appropriate for small patches of dense *C. ciliaris* with little or no shrub or tree cover on flat terrain.

Hand removal has been the initial treatment used at Uluru-Kata Tjuta National Park where *C. ciliaris* is being tackled on a different scale. Park personnel mapped 300 ha of *C. ciliaris* within the Park in 2003; a ten-fold increase on what was mapped in 1991. Crews of rangers, volunteers and field staff chipped out 12 ha of *C. ciliaris* over a year at a cost of $50 000 (Thomas Konieczny personal communication). Ongoing treatment of regrowth includes hand pulling and herbicides. The recovery of these areas has been improved by leaving chipped grass tussocks in situ (hence forming a mulch layer through which fewer seedlings re-establish), filling in holes and soil disturbances with compacted soil (to minimize wind blown *C. ciliaris* seed accumulations), and scattering native grass seed into any remaining disturbed soil (Thomas Konieczny personal communication).

Parks and Wildlife rangers are presently moving towards the use of residual herbicides for fence lines and small, isolated patches of *C. ciliaris* (usually single plants). The use of residual herbicides has been recommended as an alternative to grading/slashing fence lines due to time efficiency and reduced potential for soil erosion. This option is particularly applicable to remote areas where it is unlikely that rangers will return for follow-up control.

Substantial effort is put into data collection at weed control sites on the NT Parks and Wildlife reserve estate. Rangers are trained in the use of mapping software, and data collected from each *C. ciliaris* control site includes location, dimensions, plant phenology, crown separation ratio or number of plants, treatment and a measure of time and resources spent on treatment. This data is incorporated into an automated annual report that allows park mangers to assess weed control works and resources. It is anticipated that the data could be analysed in order to answer specific management questions.

Off-reserve *C. ciliaris* control occurs on some other tenures including private property using mostly hand removal and herbicides. The Bushfires Council, the Fire and Rescue Service, Greening Australia, Arid Lands Environment Centre, Land for Wildlife and Landcare have all identified *C. ciliaris* as an issue for concern in arid NT. Despite this, *C. ciliaris* does not fit the criteria of a declared weed species under current legislation, which allows the continued dispersal and propagation of the species.

Conclusion

There is little dispute that *C. ciliaris* now covers large areas of arid NT and has dispersed widely beyond areas where it was intentionally sown. Its invasive nature precludes it from being isolated to its intended area of benefit. The discussion of *C. ciliaris* costs and benefits to central Australia remains contentious largely due to the lack of firm data on either side. Although additional data may help to clarify some aspects of the costs and benefits associated with its presence, there is sufficient evidence to indicate that dense *C. ciliaris* is impacting on some of the most diverse habitats in arid NT. Strategies must be put in place to minimize the impacts of *C. ciliaris* in key areas for biodiversity conservation and to prevent it from invading areas that are presently free of *C. ciliaris*. There needs to be greater levels of funding to implement strategies and a legal recognition of the threat *C. ciliaris* presents so that new introductions are regulated.

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