

**IMPACTS AND MANAGEMENT OF *CENCHRUS CILIARIS*
(BUFFEL GRASS) AS AN INVASIVE SPECIES IN NORTHERN
QUEENSLAND**

Thesis submitted by
Janice JACKSON B.Agr.Sc. (Hons 1) (U.Q)
in May 2004

For the degree of Doctor of Philosophy
In Tropical Plant Sciences
School of Tropical Biology
James Cook University

STATEMENT OF ACCESS

I, the undersigned, the author of this thesis, understand that James Cook University will make it available for use within the University Library and, by microfilm or other means, allow access to users in other approved libraries. All users consulting this thesis will have to sign the following statement:

In consulting this thesis I agree not to copy or closely paraphrase it in whole or in part without the written consent of the author; and to make proper public written acknowledgement for any assistance which I have obtained from it.

.....

Janice Jackson

STATEMENT OF SOURCES DECLARATION

I declare that this thesis is my own work and has not been submitted in any form for another degree or diploma at any university or other institution of tertiary education. Information derived from the published or unpublished work of others has been acknowledged in the text and a list of references is given.

.....

Janice Jackson

Abstract

Cenchrus ciliaris L. (buffel grass) (Poaceae) is recognized as one of Australia's most serious environmental weeds. This introduced grass is associated with loss of native species and alteration of fire regimes. However there is considerable controversy regarding its weed status as it is also highly valued as a pasture species for arid and semi-arid zones. Quantitative studies are needed to determine its ecological effects. In addition, its spread into non-target areas, including conservation reserves, means that there is considerable interest in strategies for containing or eliminating *C. ciliaris*. These two issues, the effects of *C. ciliaris* on native species and strategies for managing *C. ciliaris*, are the focus of this thesis.

The relationship between *C. ciliaris* and herbaceous species richness was investigated in two studies at a range of scales up to 64 m² in open woodlands in north-eastern Queensland. In the first study, the herbaceous species composition of sites with and without *C. ciliaris* were compared. *Cenchrus ciliaris*-dominated sites had fewer herbaceous species than non-*C. ciliaris* sites at all scales investigated and this pattern was found for the major plant groups (perennial grasses, legumes and other forbs) present. In the second study, the relationship between varying levels of *C. ciliaris* biomass and species richness was investigated at one site. The relationship between varying levels of a dominant native grass, *Bothriochloa ewartiana* (Domin) C.E. Hubb. (Poaceae), and species richness was also determined for comparison with the *C. ciliaris* biomass-richness relationship. In this study, species richness was negatively associated with increasing *C. ciliaris* biomass at some scales and it appeared that *C. ciliaris* had a greater effect on richness than *B. ewartiana*. The negative association between *C. ciliaris* and species richness is consistent with the view that invasion by *C. ciliaris* poses a threat to biodiversity. However, the precise cause of the relationship has yet to be determined.

The strategic use of fire offers potential to control unwanted species. To evaluate fire as a tool for reducing *C. ciliaris* abundance, the effects of season of burning on two *C. ciliaris*-dominated communities in north Queensland were investigated. Three treatments were imposed in small plots at both sites: early dry season burn, late dry season burn and control (no burn). These treatments were selected to exploit differences in fire characteristics and vegetation responses to fire associated with different season of burning. The herbaceous species present and their cover were recorded before and after the fires and post-fire seedling emergence was monitored. To help understand the mechanisms by which fire may alter community composition, burning treatment effects on the availability of establishment sites and propagules were also investigated. Fire affects establishment site availability by

reducing resident plant competition, by altering nutrient availability and by altering soil surface condition. Three studies were conducted to investigate treatment effects on establishment sites: (1) *C. ciliaris* plants were monitored to determine mortality, (2) a bioassay technique was used to assess plant nutrient availability and (3) a 'pot' experiment was conducted to examine the effects of different soil surface cover on seedling emergence to help predict the effects of litter removal on emergence patterns. Fire effects on propagule supply were investigated by monitoring flowering in *C. ciliaris*. A germination method was used to determine soil seed bank composition.

Overall, burning had little effect on these communities. The intensities of the fires were low to moderate (300-3030 kWm⁻¹). At Dalrymple there was an unexpected reversal of intensities; the mean intensity of early dry season fires was higher than that of late dry season fires. The fires caused no major changes in composition, few *C. ciliaris* plants were killed and no changes in nutrient availability or seed bank composition were detected. Although these short-term studies of single fires do not allow definitive recommendations regarding the use of fire to manage *C. ciliaris*, they provide information that will aid future research. I found that fire could kill *C. ciliaris* plants and reduce *C. ciliaris* cover. This contrasts with the positive fire feedback model generally proposed for *C. ciliaris*. *Cenchrus ciliaris* mortality was higher with early dry season burning at Dalrymple, suggesting that higher intensity fires will be more effective in eliminating *C. ciliaris* plants and/or that *C. ciliaris* plants may be more susceptible to fire at this time because they have not fully senesced. Apparent low densities of perennial grass seeds in the seed banks of these communities may be exploited: over-sowing with native perennial grasses after fire may encourage shifts in perennial grass dominance.

There is an urgent need for management strategies that reduce, prevent or contain invasive weed invasion. Further work is required to investigate the application of fire regimes in *C. ciliaris*-dominated communities. Of particular interest are differences in growth and/or phenology between *C. ciliaris* and native species in these grasslands that may be exploited to disadvantage *C. ciliaris*.

CONTENTS

Statement of Sources Declaration.....	ii
Statement of Access.....	ii
Abstract.....	iii
List of Tables.....	ix
List of Figures.....	x
Acknowledgements.....	xiv

CHAPTER 1. GENERAL INTRODUCTION	1
1.1. <i>Cenchrus ciliaris</i> (buffel grass) – wonder grass or weed?	1
1.2. The Issues: impacts and management	2
1.3. This project	3
CHAPTER 2. <i>CENCHRUS CILIARIS</i> AS AN INVASIVE SPECIES	5
2.1. Literature review: impacts of invasive plants	5
2.1.1. Introduction	5
2.1.1.1. This review	6
2.1.1.2. A note on terminology	6
2.1.2. Biological invasions	8
2.1.3. Impacts of invasive plants	10
2.1.3.1. Impacts on ecosystem structure/components	11
2.1.3.2. Impacts on ecosystem function/processes	15
2.1.3.3. Mechanisms underlying invasive plant impacts	21
2.1.4. Grasses: a family of problem plants	22
2.1.5. Invasive plants in Australia	25
2.1.5.1. Weeds or wonder plants	27
2.1.6. <i>Cenchrus ciliaris</i>	29
2.1.6.1. Origin, introduction and establishment in Australia	30
2.1.6.2. Physical description and growth characteristics	31
2.1.6.3. <i>Cenchrus ciliaris</i> – valuable pasture species or destructive invader?	32
2.1.7. Measurement and assessment of invasive plant impacts	34
2.1.7.1. What to measure	34
2.1.7.2. How to measure plant impacts	35
2.1.7.3. Impact assessment	36

2.1.8. Conclusions	37
2.2. Is there a relationship between herbaceous species richness and <i>Cenchrus ciliaris</i> abundance?	39
2.2.1. Introduction	39
2.2.2. Methods	40
2.2.2.1. Study area	40
2.2.2.2. Study one: herbaceous species richness with and without <i>Cenchrus ciliaris</i>	41
2.2.2.3. Study two: herbaceous species richness with varying <i>Cenchrus ciliaris</i> biomass	42
2.2.3. Results	45
2.2.3.1. Study one: herbaceous species richness with and without <i>Cenchrus ciliaris</i>	45
2.2.3.2. Study two: herbaceous species richness with varying <i>Cenchrus ciliaris</i> biomass	48
2.2.4. Discussion	53
CHAPTER 3. MANAGING <i>CENCHRUS CILIARIS</i>-DOMINATED VEGETATION WITH FIRE	60
3.1. Introduction	60
3.2. Literature review: the role of fire as a vegetation management tool	64
3.2.1. Introduction	64
3.2.2. Fire: an ecological phenomenon	65
3.2.2.1. Fire type	65
3.2.2.2. Fire behaviour	66
3.2.2.3. Fire regime	67
3.2.2.4. The effects of fire	69
3.2.2.5. Plant responses to fire	70
3.2.3. Fire as a management tool for invasive plant control	73
3.2.3.1. The importance of fire regime	74
3.2.3.2. The importance of vegetation characteristics	77
3.2.3.3. The importance of other factors	80
3.2.3.4. The efficacy of fire as a tool to manage vegetation composition	81
3.2.3.5. Community responses to fire: creating gaps and filling them	84
3.2.4. <i>Cenchrus ciliaris</i> and fire	85
3.3. Site and treatment descriptions	88

3.3.1. Study sites	88
3.3.1.1. Dalrymple National Park	88
3.3.1.2. Moorrinya National Park	90
3.3.2. Experimental design and treatments	90
3.3.3. Pre-fire measurements	91
3.3.3.1. Plant species composition	91
3.3.3.2. Fuel biomass and moisture content	92
3.3.3.3. Weather conditions	92
3.3.4. Fire conditions	93
3.3.4.1. Early dry season fires	93
3.3.4.2. Late dry season fires	94
3.3.5. Local rainfall	95
3.4. Can fire kill <i>Cenchrus ciliaris</i>?	96
3.4.1. Introductions	96
3.4.2. Methods	97
3.4.2.1. Field set-up	97
3.4.2.2. Statistical analyses	98
3.4.3. Results	98
3.4.4. Discussion	101
3.5. Does fire increase plant nutrient availability in <i>Cenchrus ciliaris</i>-dominated grassland?	104
3.5.1. Introduction	104
3.5.2. Methods	106
3.5.2.1. Soil collection and processing	106
3.5.2.2. Pot set up	107
3.5.2.3. Statistical analysis	108
3.5.3. Results	108
3.5.4. Discussion	109
3.6. Litter: a help or a hindrance to seedling emergence?	112
3.6.1. Introduction	112
3.6.2. Methods	116
3.6.2.1. Treatments	116
3.6.2.2. Experimental details	116
3.6.2.3. Statistical analyses	118
3.6.3. Results	119
3.6.4. Discussion	123

3.7. Effects of season of burning on soil seed banks of <i>Cenchrus ciliaris</i>-dominated grassland	129
3.7.1. Introduction	129
3.7.2. Methods	131
3.7.2.1. Soil collection and processing	131
3.7.2.2. Glasshouse set up	131
3.7.2.3. Measurements	132
3.7.2.4. Statistical analyses	132
3.7.3. Results	133
3.7.4. Discussion	137
3.8. Does fire promote flowering in <i>Cenchrus ciliaris</i>?	144
3.8.1. Introduction	144
3.8.2. Methods	144
3.8.2.1. Measurements	144
3.8.2.2. Statistical analyses	145
3.8.3. Results	145
3.8.4. Discussion	146
3.9. Effects of season of burning on seedling emergence patterns in <i>Cenchrus ciliaris</i>-dominated grassland	149
3.9.1. Introduction	149
3.9.2. Methods	151
3.9.2.1. Seedling monitoring sites	151
3.9.2.2. Study 1: seedling recruitment study	151
3.9.2.3. Study 2: grass seedling recruitment and survival	151
3.9.3. Results	153
3.9.4. Discussion	156
3.10. Effects of season of burning on herbaceous community composition of <i>Cenchrus ciliaris</i>-dominated grassland	160
3.10.1. Introduction	160
3.10.2. Methods	161
3.10.2.1. Plant surveys	161
3.10.2.2. Statistical analyses	162
3.10.3. Results	163
3.10.4. Discussion	168
3.11. General discussion: managing <i>Cenchrus ciliaris</i> with fire	174
3.11.1. The effects of season of burning on <i>Cenchrus ciliaris</i> -dominated	

grassland	174
3.11.1.1. Effects of fire on establishment sites	175
3.11.1.2. Effects of fire on propagule supply	177
3.11.2. Fire as a management tool – are there opportunities to reduce <i>Cenchrus ciliaris</i> abundance?	179
3.11.3. Conclusions	181
CHAPTER 4. CENCHRUS CILIARIS AS AN INVASIVE SPECIES – FUTURE RESEARCH QUESTIONS	183
REFERENCES	186
APPENDICES	215
1A. Herbaceous species found in <i>C. ciliaris</i> and non- <i>C. ciliaris</i> plots in the Dalrymple Shire survey	215
1B. Herbaceous species found in surveyed plots at Hillgrove	218
2A. Aussie peat components	219
2B. Germinable seed content of <i>Cenchrus ciliaris</i> and <i>Heteropogon contortus</i> seed material	219
3A. Herbaceous species found in the Dalrymple seed banks	220
3B. Herbaceous species found in the Moorrinya seed banks	221
4A. Herbaceous species found in burning treatment plots at Dalrymple	222
4B. Herbaceous species found in burning treatment plots at Moorrinya	223

LIST OF TABLES

Table 2.1.	Some introduced grasses considered to be problematic in Australia.	27
Table 2.2.	Latitude and longitude, soil type and current grazing regimes of <i>C. ciliaris</i> and non- <i>C. ciliaris</i> plots surveyed in the Dalrymple Shire.	41
Table 2.3.	Summary of regression analyses investigating relationships between biomass and herbaceous species richness at scales 2-64 m ² for (a) <i>C. ciliaris</i> and (b) <i>B. ewartiana</i> .	51
Table 2.4.	Summary of regression analyses investigating relationships between	

	<i>C. ciliaris</i> biomass and the numbers of species of forbs, legumes, forbs plus legumes and grasses at scales from 2-64 m ² .	52
Table 3.1.	Summary of conditions for early and late dry season fires at Dalrymple and Moorrinya National Parks.	94
Table 3.2.	Mean basal area (cm ²) and mortality (%) of tagged plants at Dalrymple and Moorrinya.	99

LIST OF FIGURES

Figure 2.1.	Mean (\pm SE) numbers of species for <i>C. ciliaris</i> (■) and non- <i>C. ciliaris</i> plots (□) at each of seven scales from 1-64 m ² . Figure (a) shows the total number of species. Figures (b-d) show numbers of non-leguminous forb, legume and perennial grass species respectively.	46
Figure 2.2.	Proportional composition, in terms of numbers of non-leguminous forb, legume, sedge, annual grass and perennial grass species, of <i>C. ciliaris</i> plots (■) and non- <i>C. ciliaris</i> plots (□) at (a) 1 m ² and (b) 64 m ² scales.	47
Figure 2.3.	Herbaceous taxa showing contrasting distribution between <i>C. ciliaris</i> and non- <i>C. ciliaris</i> plots. The number of shaded cells indicates the number of plots in which the species was present.	48
Figure 2.4.	Composition of 18 plots in terms of <i>C. ciliaris</i> (■), <i>B. ewartiana</i> (□), and other herbaceous species (▣) biomass (g/m ²) at the 64 m ² scale, presented in order of declining <i>C. ciliaris</i> biomass.	49
Figure 2.5.	Herbaceous species number in relation to dominant species (<i>C. ciliaris</i> or <i>B. ewartiana</i>) biomass (g/m ²) for <i>C. ciliaris</i> (◆) and <i>B. ewartiana</i> (□) dominated plots at (a) 0.25 m ² , (b) 0.5 m ² and (c) 1 m ² scales.	50
Figure 3.1.	Location of Dalrymple and Moorrinya National Parks.	89
Figure 3.2.	Monthly precipitation (bars) recorded from June 1998 to June 2001 at (a) Fletcher View Station near Dalrymple National Park and (b)	

	Moorrinya National Park (except from September 1999 to September 2000 when precipitation for nearby Uanda Station is given).	95
Figure 3.3.	Percentage of tagged plants in basal area size classes (increments of 100 cm ²). (a) <i>C. ciliaris</i> plants at Dalrymple, (b) <i>C. ciliaris</i> plants at Moorrinya and (c) <i>Astrebla</i> plants at Moorrinya.	100
Figure 3.4.	Relationships between plot fire intensity and percentage of tagged plants that died/plot at (◆) Dalrymple and (□) Moorrinya.	101
Figure 3.5.	Mean (± SE) total above-ground biomass (g/pot) of sorghum plants grown in soil from (□) control (no burn), (■) early dry season burn and (■) late dry season burn plots at Dalrymple and Moorrinya.	108
Figure 3.6.	Relationship between plot fire intensity (kW/m) and mean total above ground sorghum biomass (g/pot) for (◆) Dalrymple and (■) Moorrinya.	109
Figure 3.7	Litter mat between <i>C. ciliaris</i> tussocks at Dalrymple	115
Figure 3.8.	Soil surface cover types with <i>H. contortus</i> seed. From left to right: eucalypt litter, matted litter, bare soil and open litter.	118
Figure 3.9.	Mean percentage emergence of (a) <i>C. ciliaris</i> seedlings and (b) <i>H. contortus</i> seedlings from four cover types (bare soil (◆), matted litter (Δ), open litter (x) and eucalypt litter (□)) over 21 days.	119
Figure 3.10.	Mean percentage emergence of <i>C. ciliaris</i> plus <i>H. contortus</i> seedlings from four cover types (bare soil (◆), matted litter (Δ), open litter (x) and eucalypt litter (□)) from seed sown top of litter (solid line) and under litter (dashed line) over 21 days.	120
Figure 3.11.	Mean percentage emergence of <i>C. ciliaris</i> seedlings (x), and <i>H. contortus</i> seedlings (□) from seed sown on top of litter (solid line) and under litter (dashed line) over 21 days.	121
Figure 3.12.	Mean days taken for 50% emergence of <i>C. ciliaris</i> seedlings (lower solid bars) and <i>H. contortus</i> seedlings (upper unfilled bars) from seed sown on bare soil and under and on top of three litter types.	122
Figure 3.13.	Mean (± SE) percentage of soil cover types at Dalrymple in January	122

2001.

- Figure 3.14.** Mean number (counts/m²) of (a) annual grass, (b) perennial grass, (c) forb, (d) legume and (e) sedge seedlings from unburnt (control), early dry season and late dry season burnt seed banks from Dalrymple (1st column) and Moorrinya (2nd column). 134
- Figure 3.15.** Percentages of perennial grass, annual grass, forb, legume and sedge plant groups making up the seed bank seedlings (1st bar) and post-fire standing herbaceous plant cover (2nd bar) at Dalrymple (left) and Moorrinya (right). 135
- Figure 3.16.** Mean species richness (number of species/plot) of seedlings emerging from unburnt (control), early dry season and late dry season burnt seed banks from Dalrymple and Moorrinya. 136
- Figure 3.17.** Relationships between plot fire intensity (kW/m) and plot species richness (number of species/plot) for (a) Dalrymple and (b) Moorrinya seed banks. 136
- Figure 3.18.** Mean number of inflorescences per tagged plant at (a) Dalrymple (all plants in January 2000) and (b and c) Moorrinya (*C. ciliaris* and *Astrelba* spp. plants respectively in February 2000) in control (no burn), early dry season fire and late dry season fire treatments. 146
- Figure 3.19.** Mean percentage of tagged plants in flower at (a) Dalrymple (all plants in January 2000) and (b and c) Moorrinya (*C. ciliaris* and *Astrelba* spp. plants respectively in February 2000) in control (no burn), early dry season fire and late dry season fire treatments. 147
- Figure 3.20.** Mean number of forb seedlings (solid bars) and grass seedlings (unfilled bars) in control, early dry season and late dry season fire plots at Dalrymple in December 1999. Different lower case letters denote significantly different forb seedling numbers. 153
- Figure 3.21.** Relationships between estimated plot fire intensity and mean number of grass (Δ) and forb (\blacksquare) seedlings/m². 154
- Figure 3.22.** Mean number of grass seedlings (seedlings/m²) found in control (no burn), early dry season and late dry season fire treatments showing seedling status (dead \blacksquare and surviving \square) at the end of the 2000-2001

	growing season (June 2001).	155
Figure 3.23.	Mean (\pm SE) species richness (number of species/m ²) in control, early and late dry season burn treatments for (a,b) annual grasses, (c,d) perennial grasses, (e,f) non-leguminous forbs and (g,h) legumes at Dalrymple (1 st column) and Moorrinya (2 nd column).	164
Figure 3.24.	Mean <i>C. ciliaris</i> percentage cover (shaded portion) and total perennial grass percentage cover (bar) cover at (a) Dalrymple and (b) Moorrinya.	165
Figure 3.25	Mean (\pm SE) percentage cover of (a) annual grasses, (b) forbs, (c) legumes and (d) sedges at Dalrymple (1 st column) and Moorrinya (2 nd column).	166
Figure 3.26	Relationship between fire intensity and perennial grass cover at (Δ) Dalrymple and (\blacksquare) Moorrinya.	167

ACKNOWLEDGEMENTS

This project would not have been possible without the support of Paul Williams, Queensland Parks and Wildlife Service. Paul provided access to field sites and assistance with field work and I thank him very much for his support and enthusiasm. Thanks also to QPWS staff Benton Haigh, Ken McMahon and Eddie Staier who assisted with the fire work and others who assisted with access to field sites and with field work including Brett Abbott, Peter Allen, Jeff Corfield, Mandy Kotzman, Brigid McCallum, Mike Nicholas, Peter O'Reagan, Ian Radford, Gary Rogers, Lynn Walker, Lindsay Whiteman and Mike Whiting. John Childs, while director of the Tropical Savanna CRC, approved funding to support some of this work. I would also like to thank him for financial support to attend a conference in Townsville and a writing course in Darwin. Thanks also to Brett Abbott for regular help with computer matters, Christy Matthes for library assistance and Chris Stokes for informative discussions regarding species area curves among other things. Many thanks to Betsy Jackes for seeing me through the university hoops. She and Tony Grice provided valuable feedback during the writing of this thesis. I would also like to thank John McIvor, John Ludwig and other reviewers for their advice on an associated manuscript that assisted with the writing of the second chapter of this thesis. The various studies were undertaken in consultation with a very patient statistician. Thank you Bob Mayer, senior biometrician with the Department of Primary Industries. Finally, I would like to thank friends, family and my husband for their support.