11-1999

Vegetation trend in the Fitzroy region. An analysis of 1995 and 1998 ground monitoring data.

Noelene Duckett

Paul Novelly

Ian Watson

National Landcare Program (Australia)

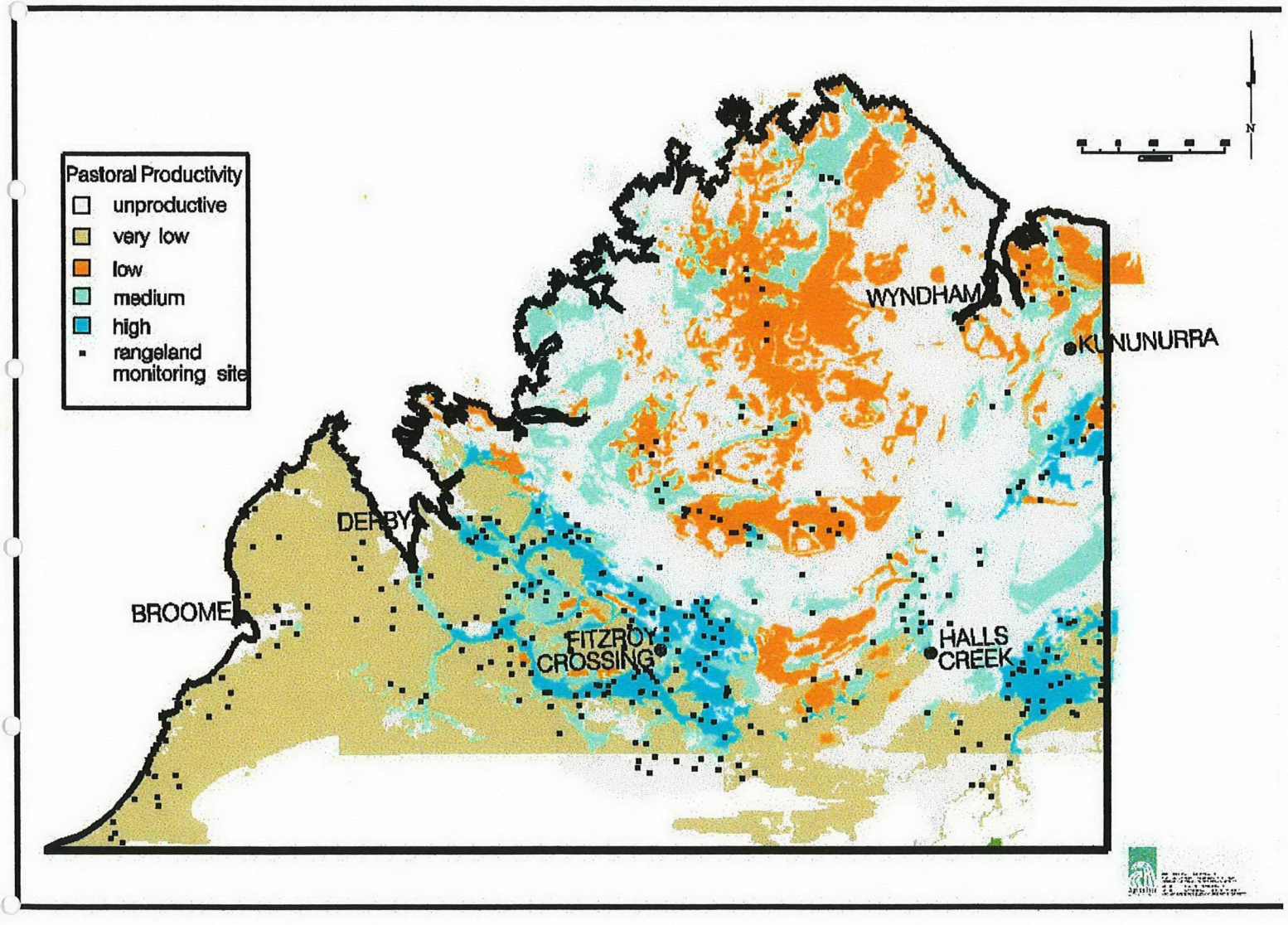
CSIRO

VEGETATION TREND IN THE FITZROY REGION

An analysis of 1995 and 1998 ground monitoring data

DEVELOPMENT OF INFORMATION PRODUCTS FOR REPORTING RANGELAND CHANGES

Noelene Duckett, Ian Watson and Paul Novelly
Agriculture Western Australia
November 1999


Pastoral Productivity
unproductive
very low
low
medium
high
rangeland monitoring site
N
WYNDHAM
KUNUNURRA
DERBY
BROOME
FITZROY CROSSING
HALLS CREEK

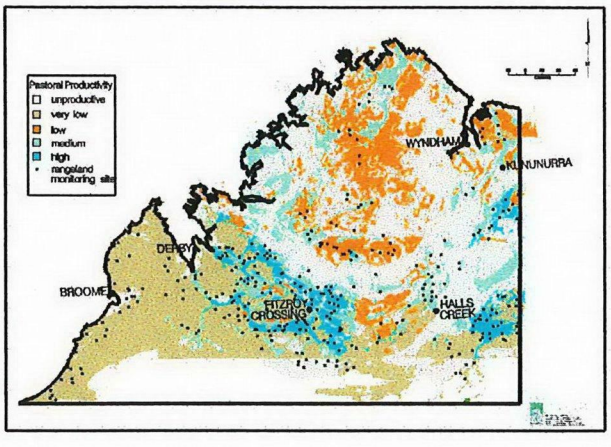

Pastoral Productivity
unproductive
very low
low
medium
high
rangeland monitoring site
WYNDHAM
KUNUNURRA
DERBY
BROOME
FITZROY CROSSING
HALLS CREEK

Table of Contents

1. Introduction

1.1 Report outline

This document summarises the analyses carried out on the ground monitoring data from the Kimberley region of Western Australia as part of the Natural Heritage Trust project 953024 - "Development of Information Products for Reporting Rangeland Changes."

This project has been investigating ways of integrating rangeland trend information collated from Landsat satellite data and site-specific ground vegetation data. This has been carried out by extending and refining previous approaches developed by Agriculture Western Australia and CSIRO Mathematical and Information Sciences (*e.g.* Wallace *et al.* 1994). The principal objective of the project is to develop useful information products which can be used for the reporting of changes in rangeland ecosystems.

As it is not sensible, nor even possible, to carry out the development of such a system over the entire Western Australian rangelands, studies have concentrated on the savanna grasslands of northern Australia. This area was selected as it encompasses a large proportion of Australia's rangelands (1 million km^2 or approx. 15%) and because it is a focus of sustainability research through the CRC for the Sustainable Development of Tropical Savannas.

Three specific test areas were identified for further study: east of Halls Creek in the East Kimberley; around Fitzroy Crossing in the West Kimberley; and adjacent to Karratha in the Pilbara region. These particular areas were selected after considering the availability of historic (pre-1994) and current quantitative vegetation monitoring data, Landsat satellite image boundaries and the wish to encompass both the Kimberley and Pilbara grasslands. It also allowed linkages with similar projects (*e.g.* Department of Lands, Planning and Environment's monitoring work in the Victoria Rivers District of the Northern Territory) and with interested parties (*e.g.* Hamersley Iron Pty Ltd).

This study reports on the vegetation trends that have been assessed in the second of the study areas identified above, the Fitzroy region, using ground monitoring data collected in 1995 and 1998. Note that vegetation trends have been assessed from two perspectives (a) pastoral purposes, using changes in the frequency of desirable and undesirable species/groups of species, and (b) landscape function, using changes in total frequency of perennial plants. Changes in woody shrub and tree cover have also been examined.

1.2 Study region

The Fitzroy study area is located in the eastern part of the West Kimberley region of Western Australia and roughly corresponds with the area encompassed by Landsat scene 108/73 (Figure 1). This map indicates the pastoral properties within the vicinity of the study area and those included in the analyses.

Climatically, the study area can be described as 'dry tropics', with almost all of the rain falling between November and April (Fitzpatrick and Arnold, 1964). The average annual rainfall decreases from north to south across the study area, with northern areas receiving around 500-530 mm per year and the more southerly areas receiving around 380-420 mm per year. Payne *et al.* (1974) broadly describes the vegetation of the general West Kimberley as tussock grassland, consisting of perennial grasses with minor components of annual grasses and herbage. In addition to climate, the plant communities are strongly influenced by soil type, particularly as this affects the amount and availability of soil water.

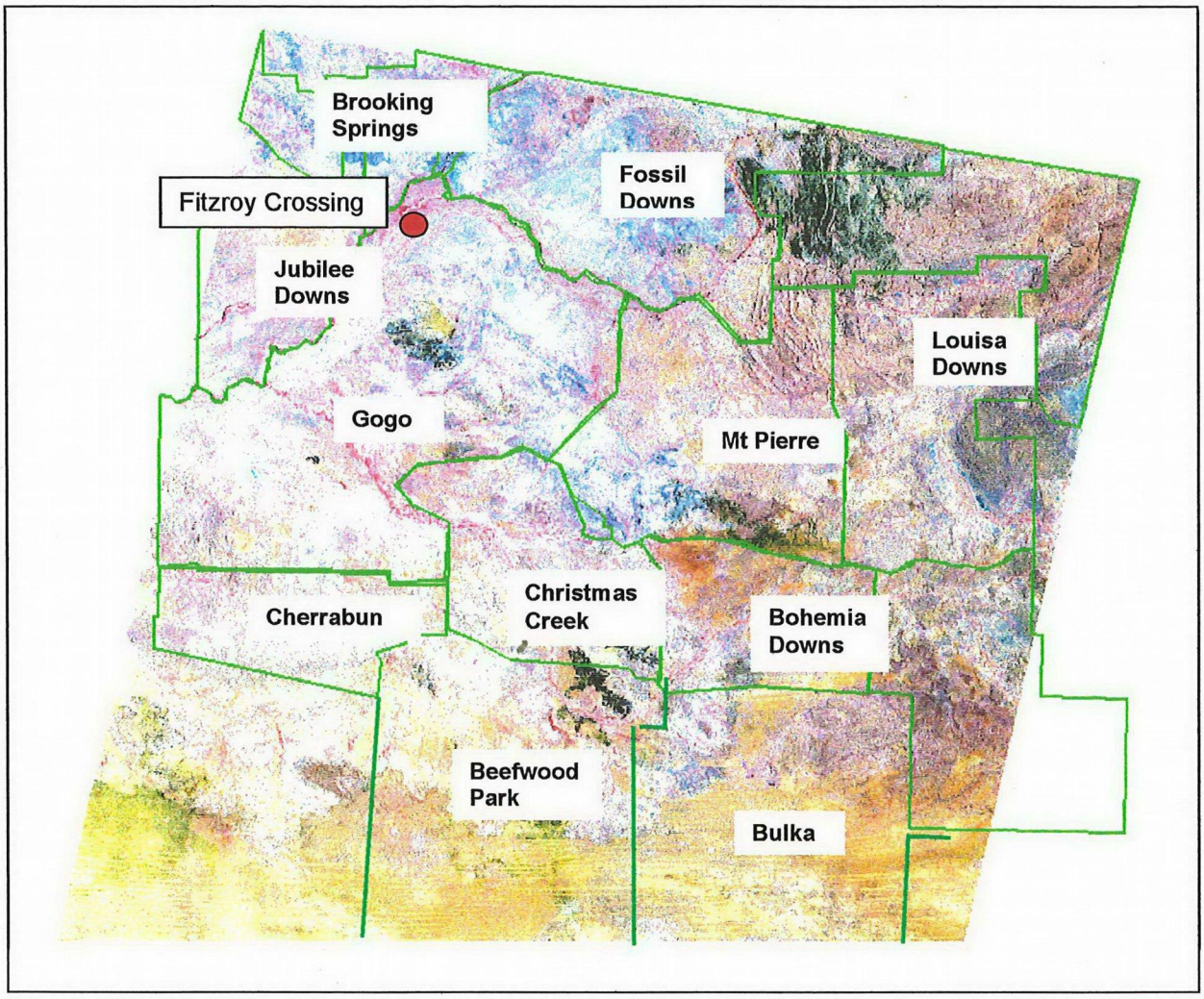


Figure 1: Fitzroy LANDSAT scene 108/73 overlain with approximate pastoral lease boundaries. The township of Fitzroy Crossing is shown in the north-western section of the study area. Landsat scene = 180km x 180 km.

1.3 Description of the ground data

1.3.1 Site and vegetation type information

Data were available for fourteen pastoral leases in the vicinity of the study area. These include Beefwood Park, Bohemia Downs, Brooking Springs, Bulka, Cherrabun, Christmas Creek, Fossil Downs, Gogo, Jubilee Downs, Leopold Downs, Louisa Downs, Mt Pierre, Noonkanbah and Quanbun Downs stations (total area of approximately 31800 km^2). Although some older data have been included in the investigations, analyses focus on the data collected when the current Western Australian Rangeland Monitoring system (WARMS) sites were installed in 1995 and when these sites were reassessed in 1998. Reassessment data were available for 74 sites.

WARMS sites are stratified across a region by vegetation type, fragility and productivity. They are located according to distance from water, representativeness of the vegetation community within each paddock or grazed areas, and for ease of access. The sites have been classified into broad vegetation types using a combination of multivariate statistical procedures including Detrended Correspondence Analysis (DCA) and hierarchical clustering (see Duckett 1997 for details). A brief description of those types encountered during this study is given in Table 1.

Table 1: Classification of vegetation at monitoring sites within the Fitzroy study region. Further details of each type are given in Duckett (1997).

Pasture Community	Soil type	Number of reassessed sites
Black soil plains (Mitchell grass)	Cracking clay	33
Southern ribbongrass	Red brown/red/yellow earths	17
Frontage grass	Alluvial floodplain	12
Curly spinifex/ribbongrass	Red and yellow sandy	9
Limestone grass	Skeletal	2
Soft spinifex	Red/yellow earths with laterite	1
Total		**74**

1.3.2 Vegetation data

Two major types of vegetation information have been collected at the monitoring sites and included in the analyses. Firstly, percentage frequency of occurrence estimates were collected for all perennial and important annual species. Estimates were generally made using 100 (0.7 m by 0.7 m) semi-permanent quadrats placed approximately 2.5 m apart along 5 marked transects. Secondly, percentage crown cover of shrubs and trees over 1 m in height was estimated using a Bitterlich gauge. Crown cover for each site was calculated as an average of estimates made at the beginning and end of transects 1, 3 and 5, *i.e.* six in total. Details of all procedures are given in the WARMS manual (Strutt *et al.* 1995).

1.4 Analysis methodology

1.4.1 Different analysis perspectives

Traditionally, rangelands have been assessed by Agriculture Western Australia from the perspective of whether or not the species present are those desirable for pastoral land use. However, there is emerging support for the view that the priority for ecosystem management must be the preservation of the productive potential of ecosystems. A well functioning landscape has numerous patches associated with perennial grasses, shrubs or trees which trap the rainfall or surface water, and retain the litter that would otherwise be washed or blown away. In a functional ecosystem there is close coupling between the rainfall, nutrients and energy trapped by the ecosystem and productivity, and the conversion of these resources into biomass is maximised. A fully functional system can potentially support the full expression of biodiversity and provides opportunities for a range of end users. Loss of these perennial plants and their associated resource-capturing patches, leads to landscape dysfunction. This may change the ability of the landscape to meet the requirements of land users.

Monitoring rangeland landscapes should, therefore, be based on the assessment of change in resource-capturing patches, through direct or indirect measures, and the frequency, dynamics and proportion of perennial species that influence the productivity or services of the landscape for the end user. Taking this into account, vegetation trends in the Fitzroy study area have been assessed from two perspectives (a) pastoral purposes, using changes in the frequency of desirable and undesirable species/groups of species, and (b) landscape function, using changes in total frequency of perennial plants.

1.4.2 Analysis techniques

Two techniques for analysing the frequency data have been used in this study, frequency plots and ordination analyses. These techniques have been described in other reports (eg Duckett 1998) and are only briefly referred to here. In some analyses, a more detailed explanation of the technique used is given to aid in interpretation. Note that separate analyses were carried out for each vegetation type. Pairwise t-tests were used to detect significant differences in some analyses.

2. Vegetation trend within the study region

Several different approaches have been used to examine vegetation trends within the Fitzroy study area. Although each of these are discussed separately in the following text, a simplified overview is presented in Appendix 1.

2.1 Assessment of trend from a pastoral perspective

2.1.1 Frequency analyses

Vegetation changes from a pastoral perspective were initially investigated by examining changes in the total frequency of the major desirable and undesirable grasses in each pasture community over the assessment period. Judgements made about whether individual species are "desirable", "intermediate" or "undesirable" were based on the usefulness of these species to pastoral production using the framework developed by Payne *et al.* (1974), rather than from a landscape function or biodiversity perspective.

Significant increases in the frequency of both desirables and undesirables were recorded overall (Table 2 and 3), although not all pasture communities showed this trend. Significant increases in desirables were noted for the black soil and frontage communities, with significant increases in undesirables recorded only for the black soil sites.

Table 2: Mean total frequency of major desirable grasses for each pasture community within the Fitzroy area. Significant differences between assessment years have been determined using paired t-tests (* = 0.01<p≤0.05; *** = p≤0.001; NS = p>0.05).

Pasture community	Number of sites	Mean freq desirables		t value & probability	Significance
		1995	1998		
Black soil plains (Mitchell grass)	33	64.4	77.0	-4.340 (p=0.000)	***
Southern ribbongrass	17	49.3	51.2	-0.896 (p=0.384)	NS
Frontage grass	12	42.9	56.3	-2.248 (p=0.046)	*
Curly spinifex/ribbongrass	9	71.4	70.0	0.639 (p=0.541)	NS
Limestone grass	2	23.0	25.5	-	
Soft spinifex	1	96	95	-	
Average across all sites	**74**	**57.6**	**65.7**	**-4.435 (p=0.000)**	***

Table 3: Mean total frequency of major undesirable grasses for each pasture community within the Fitzroy area. Significant differences between assessment years have been determined using paired t-tests (= 0.001<p≤0.01; *** = p≤0.001; NS = p>0.05).**

Pasture community	Number of sites	Mean freq undesirables		t value & probability	Significance
		1995	1998		
Black soil plains (Mitchell grass)	33	3.9	14.2	-3.408 (p=0.002)	**
Southern ribbongrass	17	0.1	0.8	-1.065 (p=0.303)	NS
Frontage grass	12	3.3	9.9	-1.564 (p=0.146)	NS
Curly spinifex/ribbongrass	9	6.3	9.7	-1.741 (p=0.120)	NS
Limestone grass	2	0	0	-	
Soft spinifex	1	0	0	-	
Average across all sites	**74**	**3.1**	**9.3**	**-3.921 (p=0.000)**	***

Following these initial analyses, frequency analyses were used to show changes in major species over time at individual sites. Sites displaying a large change (positive or negative value greater than twice the mean absolute change for any of the major species) were then highlighted. Site trends were assessed as improvements or declines depending on whether the species showing change were considered desirable or undesirable. A summary of the trend assessments for the frontage grass pastures is given in Appendix 2.

The summarised trend assessments for all of the pasture types are shown in Table 4. This table also indicates the differences in detected trends if intermediate species (*e.g.* northern wanderrie grass *Eriachne obtusa*, rat's tail couch *Sporobolus mitchellii* and black spear grass *Heteropogon contortus*) were considered in the analysis. Table 5 summarises the trend results if the two perennial *Aristida* species feathertop and threeawn were not included in the analyses. Additional analyses excluding *Aristida* were performed because it has been suggested that the dynamics of these species is influenced by recent seasonal conditions and may not consistently indicate longer term trend (Hall and Lee 1980, Lee *et al.* 1980, Foran and Bastin 1984). Note that the trends are most reliable in the pasture groups with a large number of sites and that the trends for pasture groups containing fewer sites (*i.e.* limestone grass and soft spinifex) have been judged directly from the raw data. For the limestone grass pasture community, limestone grass (*Enneapogon polyphyllus*) was included in both analyses despite its classification as an annual/short-lived perennial species.

More sites showed positive than negative trends during the assessment period when *Aristida* was included and excluded from the analyses. Generally, positive trends were noted as a result of increasing desirable grasses (*e.g.* ribbongrass, bundle bundle, native panic, birdwood grass, mitchell grass) and also intermediate value species (*e.g.* rat's tail couch, northern wanderrie grass). No sites showed a positive trend as a result of decreasing undesirable species (feathertop or threeawn). In contrast, negative trends were due to both declining desirables and/or increasing undesirables.

Table 4: Summary of trend assessment (pastoral perspective) for the Fitzroy monitoring sites. Bracketed numbers indicate changes to assessments following the inclusion of intermediate species into the analysis. The summary totals and percentages given in the last row are from the analysis excluding intermediates.

Pasture Community	Total sites	Sites showing positive trend (improving)	Sites showing no change	Sites showing negative trend (declining)	Notes
Black soil plains (Mitchell grass)	33	10 [12]	20 [18]	3	Improvements due to increases in desirables (evidence of burning at 2 sites). Declines due to decreases in desirables and increases in the undesirable feathertop. Large increases in the intermediate species rats tail couch noted at 2 sites. Two other sites showed large changes in major species - no overall trend was determined[1].
Southern ribbongrass	17	2	12	3	Improvements due to increases in the desirables ribbongrass and soft spinifex. Declines due to losses in desirables (2 sites, 1 burnt in 1997) and increases in the undesirable threeawn (1 site, burnt in 1997).
Frontage grass	12	2 [3]	9 [8]	1	Improvements due to increases in desirables ribbongrass and birdwood grass. Decline due to increasing feathertop. Increase in rats tail couch at one site.
Curly spinifex/ ribbongrass	9	2 [4]	6 [4]	1	Improvements due to increases in the desirables ribbongrass and perennial sorghum (this site did show decreasing curly spinifex). Declines due to an increase in threeawn (site burnt in 1997). Increases of the intermediate species northern wanderrie grass at 2 sites (1 burnt in 1996).
Limestone grass	2	0	1	1	Trend assessed directly from the raw data. Decline due to a decrease in the short-lived intermediate species limestone grass
Soft spinifex	1	0	1	0	Trend assessed directly from the raw data.
Total	**74**	**16 (22%)**	**49 (66%)**	**9 (12%)**	

[1] It is likely that these changes are due to the incorrect identification of species at one of the site visits. The discrepancies is likely to be solved on the next site visit.

Table 5: Summary of trend assessment (pastoral perspective) for the Fitzroy monitoring sites when changes in feathertop (*Aristida latifolia*) and threeawn (*Aristida inaequiglumis*) are not considered. Bracketed numbers indicate changes to assessments following the inclusion of intermediate species into the analysis. The summary totals and percentages given in the last row are from the analysis excluding intermediates.

Pasture Community	Total sites	Sites showing positive trend (improving)	Sites not changing	Sites showing negative trend (declining)	Notes
Black soil plains (Mitchell grass)	33	10 [12]	21 [19]	2	Improvements due to increases in desirables (evidence of burning at 2 sites). Large increases in the intermediate species rats tail couch noted at 2 sites. Two other sites showed large changes in major species - no overall trend was determined[1].
Southern ribbongrass	17	2	13	2	Improvements due to increases in ribbongrass and soft spinifex. Declines due to losses in several desirables (2 sites, 1 burnt in 1997).
Frontage grass	12	2 [3]	10 [9]	0	Improvements due to increases in desirables ribbongrass and birdwood grass. Increase in the intermediate rats tail couch at one site.
Curly spinifex/ ribbongrass	9	2 [4]	7 [5]	0	Improvements due to increases in the desirables ribbongrass and perennial sorghum (this site did show decreasing curly spinifex). Increases of the intermediate species northern wanderrie grass at 2 sites (1 burnt in 1996).
Limestone grass	2	0	1	1	Trend assessed directly from the raw data. Decline due to a decrease in the short-lived intermediate species limestone grass
Soft spinifex	1	0	1	0	Trend assessed directly from the raw data.
Total	**74**	**16 (22%)**	**53 (71.5%)**	**5 (6.5%)**	

Frequency changes can also be illustrated using frequency plots. Summary plots have been constructed for the four pasture communities with the most sites (Figure 3). These plots show the relationship between the initial frequency of all major desirable grasses at each site at time X and subsequent changes in frequency (average change per year) from time X to time X+1. The individual site changes summarised in Table 4 (analyses including intermediates and *Aristida* species) have also been indicated on the plots.

Some general observations about the data can be made from these plots. Firstly, the total frequency of major desirable species increased over the assessment period at sites with both high and low initial frequencies. Changes were greatest on the black soil and frontage pastures where frequency changes in excess of 10% per year were recorded at several sites (as indicated on Figure 3). Secondly, it is apparent that individual site trends cannot be directly determined from the summary plots. Not all sites exhibiting an increase in desirable species were rated as having a positive trend; in some cases, increases in undesirables were sufficient to cause the sites to be classified as having negative trend. Similarly, some sites exhibiting a decrease in desirables were rated as having positive trend; this was generally due to increases in the frequency of intermediate value species. One site was also rated as having positive trend despite the combined total of several small, non-significant decreases in species frequency being greater than the significant increase in frequency of a single species.

Individual species frequency plots can also be used to illustrate changes in the major species within each pasture community. These plots show the relationship between the initial frequency of each major species at each site at time X and the subsequent change from time X to time X+1. Each of the sites can also be coded to show the significance of the frequency changes as detected by the frequency analysis. The individual species frequency plots for the black soil sites are shown in Figure 3 as an example. Note that in contrast to the summary plots, the total frequency change over 3 years is shown rather than average change per year.

Although the individual species plots do not directly convey overall site trend assessments (i.e. numbers of sites showing positive trend/ no change/ negative trend), they can be used to illustrate information that

is not evident on the summary plots (shown in Figure 2). In particular they can be used to display species-specific information such as the initial species frequencies at sites showing change, or the species showing the largest changes over time. For example, the black soil species plots (Figure 3) illustrate that significant increases in the desirable species barley/hoop mitchell grass, bundle bundle and native panic generally occurred at sites with only low-medium initial frequencies of these species, while the decreases were noted at sites with higher initial frequencies. The largest increase in a species at a single site was recorded for feathertop (increase of nearly 80%) while the largest decrease recorded was for bundle bundle (decrease of nearly 80%).

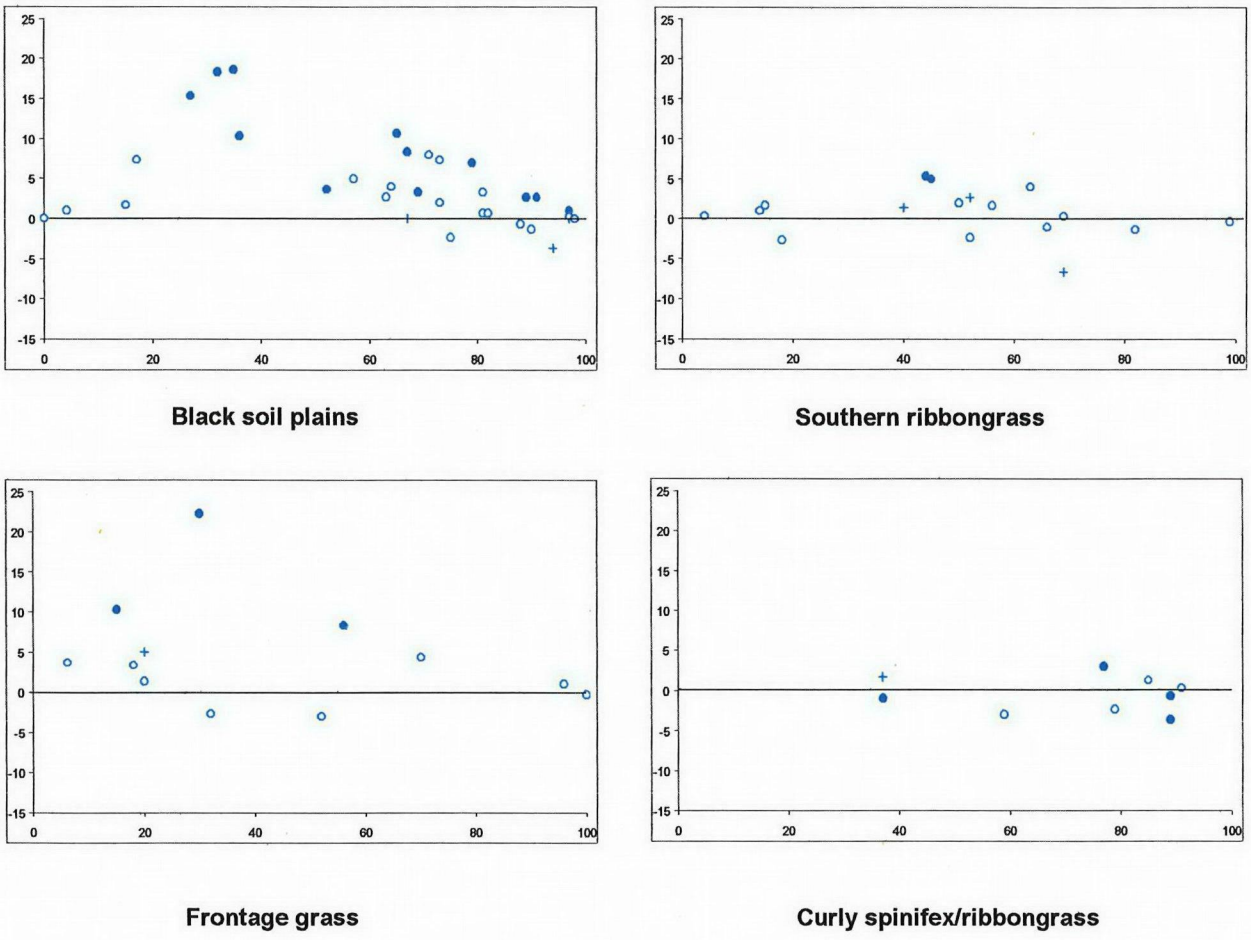
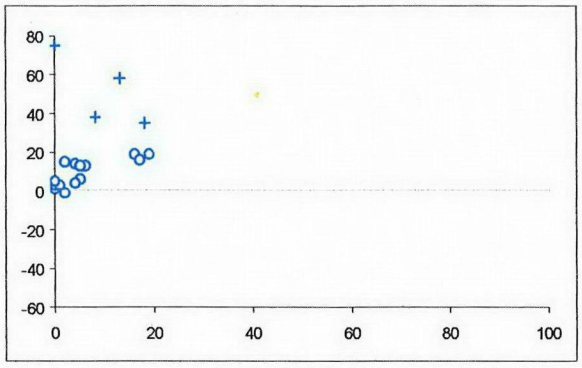
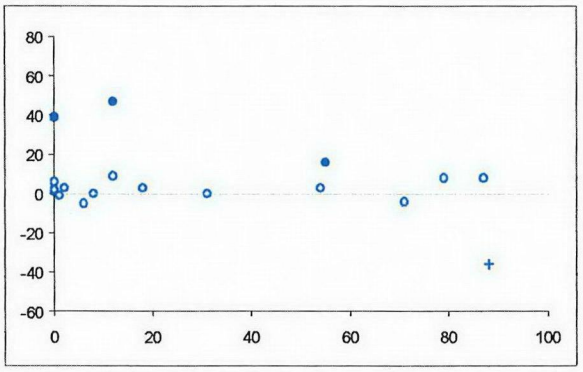


Figure 2. Frequency plots illustrating changes in frequency of major desirable species at sites within the four most common pasture communities. The x-axis represents the total initial frequency of major desirable grasses while the y-axis represents the average yearly change in frequency from time X to time X+1.

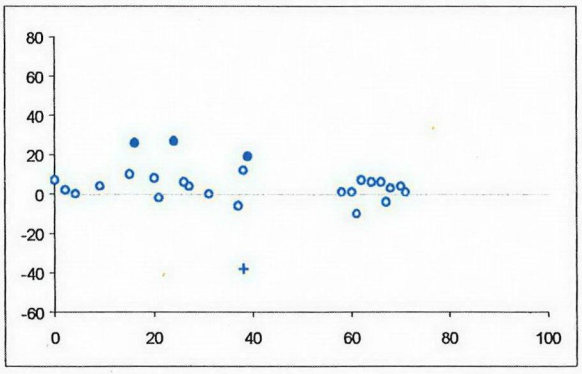
The individual site changes referred to in Table 4 have been indicated on the plot. These changes have been calculated for each pasture community separately using standard frequency analysis techniques. These analyses included intermediate value and *Aristida* species data. Changes are shown as: clear circle = site not changed; solid circle = positive trend; cross = negative trend.



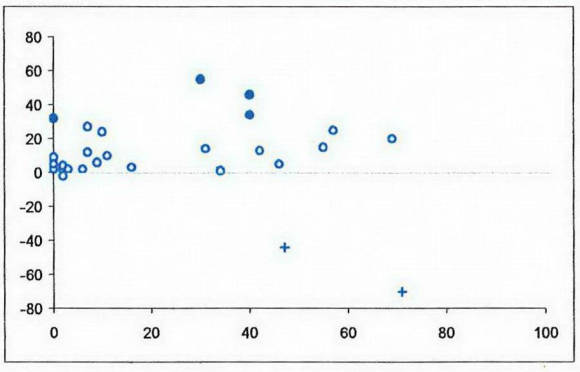
Feathertop (*Aristida latifolia*) - undesirable



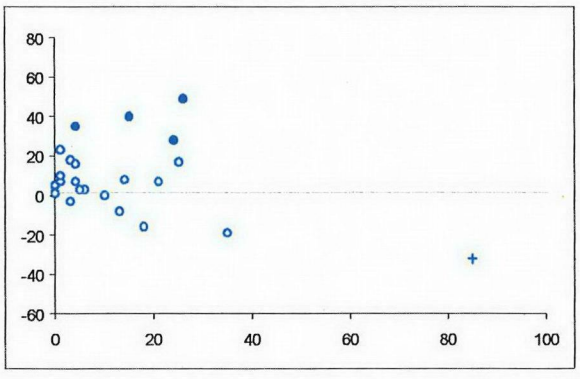
Barley and weeping Mitchell grass (*Astrebla pectinata/ A.elymoides*) - desirable



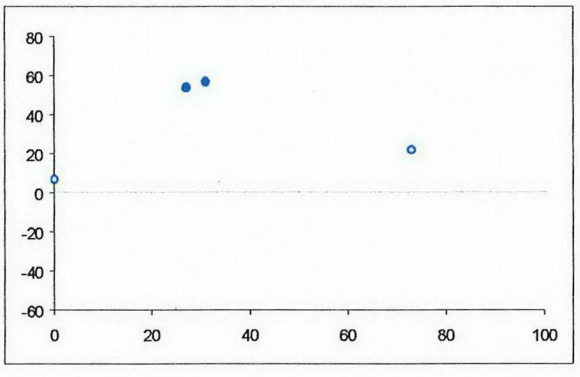
Ribbongrass (*Chrysopogon fallax*) - desirable



Bundle bundle (*Dichanthium fecundum*) - desirable



Native panic (*Panicum decompositum*) - desirable



Rat's tail couch (*Sporobolus mitchellii*) - intermediate

Figure 3: Frequency plots illustrating changes in frequency of the major perennial species for the black soil monitoring sites. The x-axis represents the initial frequency for each species while the y-axis represents the change in frequency from 1995 to 1998. For cattle production purposes, Mitchell grass, ribbongrass, bundle bundle and panic are desirable species, rat's tail couch is an intermediate species and feathertop is an undesirable species.

The significance of changes in each species were determined using standard frequency analysis techniques. Changes have been coded as follows: clear circle = site not changed for this species; solid circle = positive trend for this species; cross = negative trend for this species. Note that the overall trend for each site is subsequently determined from these individual species changes.

2.1.2 Ordination analyses

2.1.2.1 Methodology

Ordination analysis is an alternative method for examining vegetation trends which allows all species information to be included simultaneously. This technique uses vectors of trend (change) across ordination spaces, and has previously been applied to data from various rangeland communities (*e.g.* Foran *et al.* 1986, Martens *et al.* 1990). Vegetation trends can be determined via ordination analysis of either the full data (species frequencies for all assessments) or the change data (change in frequency between assessments). Ordinations are carried out using the multidimensional scaling technique known as SSH (semi-strong hybrid MDS).

Vegetation trends are determined from the ordination scores generated during the ordination analysis. As no formal statistical test is available, the amount of change (or trend) at each site is related to the length of each of the ordination axes. For the full ordinations, a site is said to have changed if the length of the trend vector (i.e. the line joining the site at time 1 and time 2 in the ordination space) on any axis is greater than 5% of the relevant axis' total length multiplied by the number of years of measurement. For the change ordinations, 'change' is indicated at sites with an ordination score that is greater than 5% of the relevant axis' total length multiplied by the number of years of measurement. These cut-off levels have been chosen as suitable given the current ecological understanding of the plant communities examined to date.

The direction of trend is determined firstly by relating the ordination axes to changes in the frequency of major species. This is done by carrying out Spearman rank correlations between the frequency values for each of the major species at each site with the SSH axis scores for that site (probabilities of ≤ 0.05 are considered significant). The major vegetation gradients acting across the ordination are then determined and movements along each axis classed as positive, negative or neutral (depending on the desirability of the changes in the context of the interpretation). The direction of individual 'changed' sites is then assessed in a similar manner. Note that the raw data for sites showing change are always checked to confirm the interpretation.

2.1.2.2 Results

Ordination analyses for the three most common vegetation types, namely the black soil plains, southern ribbongrass and frontage grass sites are shown in Table 6. For clarity, the analyses for each vegetation type has been discussed separately. Analyses were not carried out for the other groups as there were too few sites in these types for reliable results to be produced. Except where indicated otherwise, all analyses discussed here were undertaken using change data. Changes were interpreted in a pastoral context.

Black soil plains
Change ordination analyses including all perennial species suggested that change had taken place at 18 of the 33 sites (54.5%). This number decreased to 15 sites (45.5%) if the intermediate value species rat's tail couch (*Sporobolus mitchellii*) was removed from the analyses.

The direction of the site trends was not easy to determine from the correlations between the change ordination axes and the individual species frequencies. The clearest trends were visible from the plots produced from the ordination analysis excluding rat's tail couch. This analysis suggests that eight sites showed positive trend (all due to increasing desirable species) and three sites showed a negative trend (due to increasing undesirables and decreasing desirable grasses). Trend was also detected at four additional sites, however, these sites were considered to have changed little in terms of pastoral productivity. The raw data indicated changes in the frequency of different desirable grasses at these sites but not an overall trend[1]. The ordination analysis including the rat's tail couch suggested that three additional sites showed positive trend over the monitoring period due to an increase in this species.

[1] As suggested for the frequency analysis, there were species identification problems at a small number of black soil sites. The confusion was between major desirable species and is unlikely to affect the overall trend results.

Southern ribbongrass

Vegetation trends within this community were more difficult to assess and interpret than those from the other plant communities. The raw data revealed that while a large number of species did occur within this community (including grasses, shrubs and trees), individual sites were often species poor with lower frequency counts than observed in other vegetation communities.

Examination of the change vectors on the full ordination indicated that sites had changed very little over time. This small amount of overall change was also reflected in the change ordination, although in this instance the analysis suggested that nearly all sites showed trend that was above the cutoff level. This outcome is misleading and may have occurred because the observed changes (albeit small) occurred in a large number of species. This resulted in the ordination axes being correlated to a large number of species and the sites being widely distributed across the change ordination space (c.f. other plant communities where the axes were more clearly linked to the major perennial grasses). Because of these artifacts, the full ordination analyses were used in this instance.

The full ordination analyses suggested that 6 of the 17 sites (35%) changed over the monitoring period. This number decreased to 4 sites (23.5%) if northern wanderrie grass was excluded from the analyses. All the trends were quite close to the cutoff level further suggesting that smaller changes occurred than for other plant communities. As with the change ordination analyses, interpretation of the direction of these trends from the ordination plots was difficult, as the axes were correlated both positively and negatively with several of the desirable species. Examination of the ordination plots including northern wanderrie grass, and the associated raw data, suggested that positive trend occurred at three sites (due to increasing ribbongrass, birdwood grass and/or northern wanderrie grass). Trends at the other three sites could not be determined as the changes were small and often involved a number of less important species. When rat's tail couch was excluded, it is suggested that one site showed positive trend (due to increasing birdwood grass), one site showed negative trend (decreasing ribbongrass) and two sites were indeterminable in terms of trend.

Frontage grass

Ordination results suggested that five sites of the twelve sites (42%) showed detectable change over the monitoring period, with three improvements (due to an increase in desirable perennial grasses such as ribbongrass and buffel/birdwood grass) and one decline (due to increasing feathertop). One improving site did show a large decrease in sickle lovegrass (*Eragrostis falcata*) which can be an important species in some environments. As this decrease was less than the observed increase in ribbongrass, the site was still considered to be showing positive trend. Trend at the fifth site was classed as 'not changed'. This site showed a large change from feathertop to threeawn, however this was not considered as either a positive or negative trend and possibly reflects incorrect species identification at one of the site visits.

While the removal of the intermediate species northern wanderrie grass did alter the distribution of sites across the ordination space, it did not change the results for this vegetation type. This species increased slightly at most sites over the monitoring period.

Table 6: Summary of trend assessment for the Fitzroy monitoring sites using ordination analyses. Bracketed numbers indicate changes to assessments following the inclusion of intermediate species into the analysis. The summary totals and percentages given in the last row of the table are from the analysis excluding intermediates.

Pasture Community	Total sites	Sites showing positive trend (improving)	Sites not changing	Sites showing negative trend (declining)	Notes
Black soil plains (Mitchell grass)	33	8 [11]	22 [19]	3	Improvements were due to increasing desirable species. Declines were due to increasing undesirable feathertop and/or decreasing desirables. Two sites showed large increases in the intermediate species rat's tail couch. Four sites did show trend but were considered to have remained the same in terms of pastoral productivity and were classed as 'not changing'
Southern ribbongrass	17	1 [3]	13+2 [11+3]	1 [0]	Improvements due to increasing desirables. Declines due to decreasing desirables. The 'not changing' category includes sites where the direction of trend could not be assessed (shown as additional sites). Trends were generally small and difficult to assess as positive or negative.
Frontage grass	12	3	8	1	Improvements were due to increasing desirable species. Decline was due to increasing undesirable feathertop.
Total	**62**	**12 (19.5%)**	**43+2 (69.5+3%)**	**5 (8%)**	

2.2 Analysis of trend from a landscape functioning perspective

Current research suggests that the optimum functioning of a landscape is reliant on vegetation mounds or patches to regulate rainfall, surface water and litter (Ewel 1997, Tongway and Ludwig 1997). Without these patches, landscape function is reduced due to nutrients and water being lost from the system. Conversion into biomass is probably reduced (although little empirical evidence of this - but see Holm and Watson 2000 (in prep.)). In this analysis, the total frequency of perennial plants has been used as a crude indicator of landscape function. An increase in the total frequency of perennial plants has been regarded as an increase in landscape function. Conversely, a decrease in total perennials suggests reduced landscape function.

The raw results indicate an overall average increase in perennials from 1995 to 1998 (p=0.000, Table 7). This trend was consistent for all major pasture communities (significant increases were detected for the black soils, southern ribbongrass, frontage grass and curly spinifex sites), with the frontage grass sites showing the largest average increase (11.5%).

Table 7: Mean total frequency of perennials for each pasture community within the Fitzroy area. Significant differences between assessment years have been determined using paired t-tests (* =0.01<p≤0.05; ** = 0.001<p≤0.01; *** = p≤0.001; NS = p>0.05).

Pasture community	Number of sites	Mean freq perennials		t value & probability	Significance
		1995	1998		
Black soil plains (Mitchell grass)	33	73.9	84.6	-4.663 (p=0.000)	***
Southern ribbongrass	17	65.6	75.9	-3.116 (p=0.001)	***
Frontage grass	12	66.8	81.4	-2.803 (p=0.017)	*
Curly spinifex/ribbongrass	9	90.2	94.7	-2.134 (p=0.065)	NS
Limestone grass	2	24.0	27.0		
Soft spinifex	1	98.0	97.0		
Average across all sites	**74**	**71.8**	**81.9**	**-6.419 (p=0.000)**	***

Additionally, frequency analysis was used to highlight those sites showing large changes in the total perennial frequency. In this instance, analyses were carried out by firstly calculating the frequency of all perennial plants at each site. The change in frequency between visits at each site was then determined, and compared to the mean absolute frequency change across all sites for that vegetation type. As with previous frequency analyses, sites showing a positive or negative change greater than twice the mean absolute change were then defined as having 'changed'.

Trend assessment results for landscape function indicate increases in the total frequency of perennials (and hence landscape function) at 9 of the 74 sites while no decreases were noted (Table 8).

Table 8: Summary of trend assessment from a landscape functioning perspective for the Fitzroy sites.

Pasture Community	Total sites	Sites with increasing total perennials (improved landscape functioning)	Sites not changing	Sites with decreasing total perennials (reduced landscape functioning)
Black soil plains (Mitchell grass)	33	4	29	0
Southern ribbongrass	17	1	16	0
Frontage grass	12	2	10	0
Curly spinifex/ ribbongrass	9	2	7	0
Limestone grass	2	0	2	0
Soft spinifex	1	0	1	0
Total	**74**	**9 (12.2%)**	**65 (87.8%)**	**0**

2.3 Changes in woody overstorey cover

Crown cover estimates were carried out at all sites across the Fitzroy area. Changes in the average total crown cover for each pasture community have been summarised (Table 9) along with changes in *Acacia* and *Eucalyptus* cover (Tables 10 and 11). Paired t-tests were used to determine significant differences between years.

There was no significant change in the overall amount of woody cover present on the monitoring plots from 1995 to 1998. Furthermore, none of the individual pasture communities showed significant change. Separate examination of the *Eucalyptus* and *Acacia* data provides no evidence of any increase in either of these groups of species, with the overall average *Acacia* cover actually falling from 0.85% to 0.56%.

Table 9: Average crown cover estimates for all woody species > 1 m in height at the Fitzroy study sites in 1995 and 1998. Measurements were made using a Bitterlich gauge and averaged over 6 readings. Significant differences between years were determined using paired t-tests (NS = p>0.05).

Pasture community	Number of sites	Crown cover %		t value & probability	Significance
		1995	1998		
Black soils	33	2.31	2.06	0.954 (p=0.347)	NS
Southern ribbongrass	17	4.14	3.92	0.280 (p=0.783)	NS
Frontage grass	12	8.56	9.75	-1.492 (p=0.164)	NS
Curly spinifex/ribbongrass	9	6.26	5.13	1.028 (p=0.334)	NS
Limestone grass	2	0.50	0.50	-	-
Soft spinifex	1	1.50	0.67	-	-
All sites	**74**	**4.16**	**4.06**	**0.412 (p=0.682)**	**NS**

Table 10: Average crown cover estimates for all *Acacia* species >1 m in height at the Fitzroy study sites in 1995 and 1998. Significant differences between years were determined using paired t-tests (NS = p>0.05).

Pasture community	Number of sites	Crown cover %		t value & probability	Significance
		1995	1998		
Black soils	33	0.39	0.17	1.473 (p=0.150)	NS
Southern ribbongrass	17	1.60	0.87	1.021 (p=0.323)	NS
Frontage grass	12	0.92	1.38	-1.290 (p=0.224)	NS
Curly spinifex/ribbongrass	9	1.09	0.35	1.055 (p=0.322)	NS
Limestone grass	2	0.42	0.50	-	-
Soft spinifex	1	1.33	0.17	-	-
All sites	**74**	**0.85**	**0.56**	**1.432 (p=0.156)**	**NS**

Table 11: Average crown cover estimates for all *Eucalyptus* species > 1 m in height at the Fitzroy study sites in 1995 and 1998. Significant differences between years were determined using paired t-tests (NS = p>0.05).

Pasture community	Number of sites	Crown cover %		t value & probability	Significance
		1995	1998		
Black soils	33	1.20	0.98	1.132 (p=0.266)	NS
Southern ribbongrass	17	0.78	0.78	0.000 (p=1.000)	NS
Frontage grass	12	6.44	6.79	-0.471 (p=0.647)	NS
Curly spinifex/ribbongrass	9	3.48	3.07	0.879 (p=0.405)	NS
Limestone grass	2	0.00	0.00	-	-
Soft spinifex	1	0.00	0.00	-	-
All sites	**74**	**2.81**	**2.09**	**0.584 (p=0.561)**	**NS**

3. Discussion

3.1 Trends in grasses

There was a clear overall increase in the frequency of perennial plants at monitoring sites across the Fitzroy study area from 1995-1998. Additionally, the frequencies of both the major desirable and undesirable grass species in each pasture community were also seen to increase (Table 12).

Table 12: Mean frequencies of all perennials, major desirables and major undesirables for all sites in the Fitzroy study area in 1995 and 1998. All increases over the assessment period were significant at the $p<0.001$ level as detected by pair-wise t-tests.

Species included	Mean frequency	
	1995	1998
All perennials	71.8	81.9
Major desirables in each pasture group	57.6	65.7
Major undesirables in each pasture group	3.1	9.3

Trend assessment analyses indicate that a number of the monitoring sites within the Fitzroy study area had shown vegetation trend (or change) from 1995 to 1998. Furthermore, the analyses suggested that more sites had shown positive trend (improvement) than negative trend (decline). Depending on the interpretation criteria used, the frequency analyses indicated that around 12-28.5% of sites had shown positive trend, 59.5-88% had not changed and 0-12% had shown negative trend (Table 13). Although not included in the summary table below, the assessments from the ordination analyses produced similar overall trends.

Table 13: Summary of the trend assessment analyses for the Fitzroy monitoring sites. Trends were assessed by frequency analyses using the interpretation criteria indicated. Results are shown as % of the total number of sites.

Perspective	Interpretation criteria	% of sites showing positive trend (improving)	% of sites not changing	% of sites showing negative trend (declining)
Pastoral	*Aristida* included / intermediates excluded	22	66	12
	Aristida and intermediates included	28.5	59.5	12
	Aristida and intermediates excluded	22	71.5	6.5
	Aristida excluded / intermediates included	28.5	65	6.5
Landscape function	All perennials included	12	88	0

The results also indicated that while vegetation trends occurred within all major pasture groups, some groups showed a greater proportion of change (Table 14). In particular, most sites showing positive trend were black soil plains sites (approximately 60% of all positively trending sites). Changes occurred across the whole region and were not restricted to particular areas or pastoral leases. In fact, a number of leases showed both positively and negatively trending sites. As suggested earlier, positive trends were noted following increases in desirable grasses (*e.g.* ribbongrass, bundle bundle, native panic, birdwood grass and mitchell grass) and also intermediate value species (*e.g.* rat's tail couch and northern wanderrie grass). No sites showed a positive trend as a result of decreasing undesirable species (feathertop or threeawn). In contrast, negative trends were due to both declining desirables and/or increasing undesirables.

Table 14: Summary of the trend assessment analyses for each of the pasture communities in the Fitzroy study area. Trends were assessed by frequency analyses using the interpretation criteria indicated in Table 10. Results are shown as % of the total number of sites.

Pasture community	Number of sites	% of sites showing positive trend (improving)	% of sites not changing	% of sites showing negative trend (declining)
Black soils	33	12-36.5	54.5-88	0-9
Southern ribbongrass	17	6-12	70.5-94	0-17.5
Frontage grass	12	16.5	66.5-83	0-8.5
Curly spinifex/ribbongrass	9	22-44.5	44.5-78	0-11
Limestone grass	2	0	50-100	0-50
Soft spinifex	1	0	100	0

The inclusion of intermediate value species (northern wanderrie grass, rat's tail couch, black spear grass) and the undesirable *Aristida* species (feathertop, threeawn) in the analysis warrants additional comment. Although it is acknowledged that the results do differ slightly depending on the analysis criteria, it remains difficult to reach a general agreement on the importance of these species from a long term pastoral perspective. For example, while some researchers clearly see feathertop as an undesirable and invasive grass (e.g. Payne *et al.* 1974, Phelps 1999), others have indicated that an increase may not always indicate a lasting negative trend. They suggest that an increase in the frequency of feathertop is likely to be short-lived if the increase is a direct consequence of good season conditions (Hall and Lee 1980, Lee *et al.* 1980, Foran and Bastin 1984). Similarly rat's tail couch may have little value in a highly productive mitchell grass or ribbongrass community but may be an important coloniser in less productive pastures. Consequently, all the analyses results have been presented to allow the reader to make their own judgement with regard to these species.

Finally, number of issues related to the analysis of total perennials deserves mention:

1. The number of sites with increased total perennials (improved function) may have been conservatively estimated by the frequency plot analysis. A large number of sites had very high frequencies of perennial plants at the first assessment (26 of the 74 sites (35%) recorded frequencies of ≥ 90 in 1995) which may prevent increases in function from being detected.
2. The classification of a species as truly perennial (*c.f.* semi-perennial/annual) is not always definitive (Harper 1977; Silvertown and Doust 1993). A number of species show signs of perenniality in certain geographic locations or particular environments whilst clearly possessing an annual lifecycle in other environments (A Mitchell pers. comm.). This may lead to inconsistent measuring of species both between years and between locations, particularly when different assessment personnel have been involved. Over time, sampling conventions for each site will become more rigorous.
3. The raw data suggests that smaller perennials may not always be consistently measured from year to year at individual sites. This is most likely due to an incorrect assumption by the assessor that the species is not perennial, or because the species is not considered as important in the more traditional pastoral land use sense. Inconsistencies in the data recording have been reduced as much as possible.

3.2 Trends in woody shrubs and trees

There was no detectable change in the cover of woody shrubs and trees during this assessment period in any of the pasture communities or across all sites. There was also no change in the cover percentages of *Acacia* and *Eucalyptus* species. This stability in cover may be seen as a positive observation as it suggests a lack of shrub encroachment across the area, particularly of woody weeds. It is interesting that decreasing woody cover was observed at a number of sites suspected to have been recently burnt.

3.3 Summary

Analytical methods developed during the Natural Heritage Trust funded '*Development of information products for reporting rangeland changes*' project have been employed to investigate vegetation trends in the Fitzroy area from 1995-1998. This report has been compiled to provide an insight into these analytical tools and also the presentation products now available for assessing and displaying vegetation trends over time.

Trend assessment for the ground based rangeland monitoring sites in the Fitzroy area between 1995 and 1998 showed that a majority of sites remained stable. Of the sites that did change, more sites improved than declined. Trends were noted across the study region and in all six major vegetation communities.

4. References

Duckett, N.J. (1997). *A description of vegetation communities in the Kimberley: An analysis of grassland monitoring sites.* Task Report for National Landcare Program Project 'Development of Information Products for Reporting Rangeland Changes'. Agriculture Western Australia, Perth.

Duckett, N.J. (1998). *Displaying vegetation trends using the East Kimberley ground monitoring data.* Task Report for National Landcare Program Project 'Development of Information Products for Reporting Rangeland Changes'. Agriculture Western Australia, Perth. Unpublished draft.

Ewel, J.J. (1997). Ecosytem processes and the new conservation theory. *In* (S.T.A. Pickett, R.S. Ostfield, M. Shachak and G.E. Likens (eds.)) *The Ecological Basis of Conservation: heterogeneity, ecosystems and biodiversity.* Chapman and Hall, New York. p. 252-261

Fitzpatrick, E.A. and Arnold, J.M. (1964). Climate of the west Kimberley area. In *General Report on the Lands of the West Kimberley Area, W.A.* Land Research Series No 9. CSIRO, Melbourne. p. 76-102.

Foran, B.D., Bastin, G. and Shaw, K.A. (1986). Range assessment and monitoring in arid lands: the use of classification and ordination in range survey. *Journal of Environmental Management* **22**: 67 -84.

Harper, J.L. (1977). *Population biology of plants.* Academic Press, London. 892 pp.

Holm, A.McR and Watson, I. (in prep.)

Martens, J.C., Danckwerts, J.E., Stuart-Hill, G.C. and Aucamp, A.J. (1990). Use of multivariate techniques to identify vegetation units and monitor change on a livestock production system in a semi-arid savanna of the Eastern Cape. *Journal of the Grassland Society of Southern Africa* 7: 184 - 189.

Payne, A.L., Kubicki, A. and Wilcox, D.G. (1974). *Range condition guides for the West Kimberley area WA.* Western Australian Department of Agriculture, Perth. 141 pp.

Phelps, D.G. (1999). The combined stresses of spring burning and low sumer rainfall can reduce *Aristida latifolia* infestations. In (D. Eldridge and D. Freudenberger (eds)) *People and Rangeland Building the Future.* Proceedings of the VIth International Rangelands Congress, Townsville, Queensland, July 19-23, 1999. Vol 1. International Rangelands Congress Inc, Aitkenvale. p. 253-254.

Silvertown, J.W. and Doust, J.L. (1993). *Introduction to plant population biology.* Blackwell Scientific Publications, Oxford. 210 pp.

Strutt S., Handasyde, T. and Beurle, D. (1995). The Western Australian rangeland monitoring system for grasslands. Field manual. Agriculture Western Australia, Perth. Draft.

Tongway, D.J. and Ludwig, J.A. (1997). The conservation of water and nutrients within landscapes. In (J. Ludwig, D. Tongway, D. Freudenberger, J. Noble and K. Hodgkinson (eds.)) *Landscape Ecology, Function and Management: principles from Australia's rangelands.* CSIRO, Melbourne. p. 13-22.

Wallace, J.F., Holm, A. McR., Novelly, P.E. andCampbell, N.A. (1994). Rangeland monitoring and change detection using remote sensing. National Landcare Program Project 91/W/M5 - Final report. CSIRO Division of Mathematics and Statistics, Western Australian Department of Agriculture, Perth.

Appendix 1: Summary of analyses carried out using the Fitzroy ground monitoring data. In all instances, analyses have been carried out separately for each vegetation type. Details of each assessment procedure are provided in text while analysis techniques are discussed further in Duckett (1997).

Analysis Type	Objective	Data Used	Analysis Technique	Results
Vegetation trend assessment (Pastoral perspective)	To investigate changes in the mean frequency of desirable and undesirable perennials over time. • Mean frequency includes only the major grass species from each pasture type.	Frequency of major desirable and undesirable grasses at each site	Pairwise t-tests	Tables 2 and 3
	To highlight sites showing changes in the major pastoral species over time. • Site changes due to intermediate value species included separately as importance of these species is subject to debate.	Frequency of major perennial grasses each site. *Aristida* species included	Frequency analysis	Table 4 Figure 2 – Graphical display of site changes for common pasture types. Figure 3 – Graphical display of individual species changes at black soil sites
	To highlight sites showing changes in the major pastoral species (excluding *Aristida*) over time. • Site changes due to intermediate value species included separately as importance of these species is subject to debate. • *Aristida* species excluded from the analysis as changes in these species may not be indicative of long term change	Frequency of major perennial grasses each site. *Aristida* species excluded	Frequency analysis	Table 5
	To highlight sites showing changes in any perennial species over time. Desirability of change for pastoral land use determined.	Frequency of all perennial species at each site. Common pasture types only	Ordination	Table 6
Vegetation trend assessment (Landscape function perspective)	To investigate changes in the mean frequency of perennials across the study area	Total perennial frequency at each site	Pairwise t-tests	Table 7
	To highlight sites showing changes in the total frequency of perennials over time.	Total perennial frequency at each site	Frequency analysis	Table 8
Woody crown cover assessment	To investigate changes in woody crown cover across the study area.	Crown cover estimates for all woody species at each site > 1m.	Pairwise t-tests	Table 9
	To investigate changes in *Acacia* crown cover across the study area.	Crown cover estimates for all *Acacia* species > 1m.	Pairwise t-tests	Table 10
	To investigate changes in *Eucalyptus* crown cover across the study area.	Crown cover estimates for all *Eucalyptus* species > 1m.	Pairwise t-tests	Table 11

Appendix 2: Example of frequency analysis methodology for site assessments: summary of assessments for the Frontage grass pasture community.

Major points:

- It was necessary to combine the data for the two *Aristida* (feathertop and threeawn) and the two *Cenchrus* species (buffel and birdwood grass) in this pasture community. These species are difficult to distinguish in the field but are functionally similar.

- Five species groups were subsequently included in the analysis – 2 desirables, 2 intermediates and 1 undesirable.

- Analyses can take place using total frequency change from time X to Time X+1 or the average yearly frequency change. The total frequency change was used for this analysis as all sites were revisited at a three year interval.

- A significant change in any given species/species group is defined as one that is greater than twice the mean absolute change for that species across all sites at which the species is present.

- Overall site changes are determined from the individual species changes.

- Summary of the trends for the pasture community when Aristida is ***included*** in the analysis :
  - Positive trend (improvement) - 2 sites (1 increased ribbongrass,1 increased buffel/birdwood grass)
    - 1 additional site showed increased rat's tail couch (intermediate value)
  - Not changed – 9 sites (8 sites if changes in rat's tail couch is considered)
  - Negative trend (decline) – 1 site (increased *Aristida*)

- Summary of the trends for the pasture community when Aristida is ***excluded*** from the analysis :
  - Positive trend (improvement) - 2 sites (1 increased ribbongrass,1 increased buffel/birdwood grass)
    - 1 additional site showed increased rat's tail couch (intermediate value)
  - Not changed – 10 sites (10 sites if changes in rat's tail couch is considered)
  - Negative trend (decline) – 0 sites

Frequency change table:

Site	Feathertop/ Threeawn (Undesirable)	Buffel/ birdwood grass (Desirable)	Ribbongrass (Desirable)	Northern wanderrie grass (Intermediate)	Rat's tail couch (Intermediate)	Overall site Assessment
1			-3		0	Not changed
2			**31**	2		**Improved**
3	21		10	2		Not changed
4	-1	0	13			Not changed
5		**67**		17		**Improved**
6	-2	21	1	5		Not changed
7	7	-8		15		Not changed
8			4	12		Not changed
9			-9	13		Not changed
10		10	1	17		Not changed
11	**49**	2	9	0	-1	***Declined (if Aristida included)***
12			14		**9**	**[Improved]**
Twice mean absolute change	32	36	19	18.4	6.6	