THE IMPACT OF GRAZING ON PASTURE COMPOSITION IN A SANDY OPEN WOODLAND IN CENTRAL AUSTRALIA

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CONTENTS

Summary

Estimates of pasture attributes important to cattle production were made three times between 1998 and 2001 in a 128 hectare cattle exclosure, ungrazed since 1968, in sandy open woodland in central Australia. Similar estimates were conducted in the surrounding area, grazed since 1954.

The grazed area consistently produced larger amounts of the perennial grass, *Eragrostis eriopoda*. The annual grasses, *Enneapogon polyphyllus* and *Aristida contorta*, were only significant contributors to estimated production in the absence of grazing. Another dominant biennial grass, *Aristida holathera*, was unaffected by grazing.

Various forbs and minor grasses showed significant differences in estimated dry matter production and/or frequency of occurrence when seasonal conditions were favourable for their growth.

There were no differences in the diversity of pasture species between treatments. Diversity of pasture species declined after consecutive seasons of above average rainfall. *Eragrostis eriopoda* and *Enneapogon polyphyllus* had declining productivity during this period, while *Aristida holathera* continued to increase production.

Limited data is also presented on tree and shrub species, which suggests that the chenopod shrub, *Rhagodia eremaea*, had consistently higher canopy cover inside the exclosure, yet was the dominant shrub cover in the grazed treatment. Other species, such as the fodder and shade tree supplejack, *Ventilago viminalis,* require further study to assess the impact of grazing on their population ecology.

It was concluded that the relatively short 50-year history of livestock grazing at this site has resulted in a shift in pasture composition, with some deterioration in the balance of useful pasture plants. However, an equally stable vegetation state has developed, which, although not as nutritious in good seasons, is inherently more stable, particularly under drought conditions characteristic of the region.

1. INTRODUCTION

1.1. Open Woodland Pasture Type

This technical bulletin reports the changes to pasture composition that have resulted from 50 years of cattle grazing near just one central Australian bore, located in an open woodland pastureland. It is necessary to extrapolate the results to similar 'country', as no comparable study locations exist in the region, even in dissimilar land types. Furthermore, it has taken several decades at this study location for obvious pasture composition changes to develop as a result of exclusion from grazing. A detailed description of the study location can therefore help with interpreting and extrapolating the results.

The most specific description of the study location is that of Perry et al. (1962). It is classified as Kanandra land system, one of 88 land systems in the Alice Springs area, and comprising 3367 km^2 of sparsely timbered sandy plains, mainly on the northern edge of the Harts Range. Perry (1962) more broadly classifies the pasture lands of the Alice Springs area, with the present study location best described as short grass-forb pasture on young alluvia. Comprising about 12 land systems, this description allows broader extrapolation over 16,000 km^2 of similar country. Through the course of various studies since then, this pasture type has become generally known as open woodland (for example, Griffin and Friedel 1984, Squires and Low 1987).

Figure 1 shows the distribution of three open woodland land systems mapped by Perry et al. (1962), which are perhaps most similar to the study location. They are Kanandra, Hamilton, and Todd land systems comprising 5200 km^2. Figure 1 also shows that these open woodlands are scattered in unconnected pockets, flanking upland areas. These include the Reynolds and Giles Ranges between Yuendumu and Ti Tree, the western and eastern MacDonnell Ranges trending west-east through Alice Springs, and the Harts Range, north-east of Alice Springs.

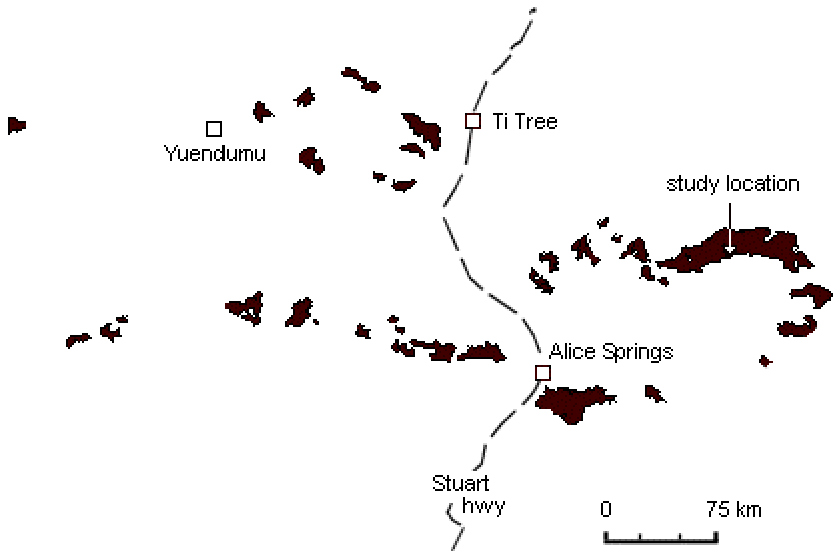

Figure 1. Distribution of open woodland pasture types in the Alice Springs region based on Perry et al. (1962) mapping of Kanandra, Hamilton, and Todd land systems. Other land systems can also be described as open woodland but these three land systems are perhaps most typical of the Spinifex bore study location, which is also shown.

The open woodland pasture is moderate to highly productive with a carrying capacity of between four and six cattle per km^2 (Bastin and Shaw 1996). It is valuable fattening country, which needs protection by light grazing during droughts to prevent death of perennial grasses and accelerated soil erosion (Condon et al. 1969). Open woodlands are characterised by scattered edible top-feeds including whitewood (*Atalaya hemiglauca*), supplejack (*Ventilago viminalis*), ironwood (*Acacia estrophiolata*), mulga (*Acacia aneura*), and witchetty bush (*Acacia* *kempeana*) (Bastin and Shaw 1996). There are various perennial grasses in areas receiving extra rainfall run-off, while dominant annual grasses include mulga grass (*Aristida contorta*) and oat grasses (*Enneapogon* spp.). More sandy plains are dominated by the less palatable woollybutt grass (*Eragrostis eriopoda*), and kerosene grass (*Aristida holathera*).

1.2. Open Woodlands and Cattle Grazing

Many open woodland plains remained ungrazed 60 years or more after pastoralists began arriving in central Australia in the 1870s. Livestock were restricted to natural waterholes and soaks in the early decades because of low capital investment within the industry. It was not until after World War II, when cattle prices and market access improved, that development programs began in many previously waterless areas through the provision of sub-artesian bores (Connellen 1965).

Investment in water supply was subsidised by the Northern Territory government during the 1960s drought (Hare 1985), when cattle numbers for the whole district plummeted from 420,000 in 1958 to just 80,000 in 1965 (Condon et al. 1969). Conversely, the 1970s became the wettest decade on record with natural herd increases accompanied by low cattle prices (Chisholm 1983). During the 1980s and 1990s there was slow but steady development of additional waters in open woodlands, often through construction of dams and reticulating water from existing bores to new grazing areas with polythene pipe. Open woodland is now amongst the most utilised and valuable grazing land in central Australia, yet little is known about the impact that 50 years or so of cattle grazing has had on pasture production and composition.

1.3. Spinifex Bore Exclosure

The current study utilises the relatively large cattle exclosure measuring 1.6 km long and 0.8 km wide established in July 1968 on Mt. Riddock station, 150 km north east of Alice Springs. Located in sandy open woodland, the exclosure starts 1.6 km from Spinifex bore, which was first equipped in 1954, suggesting 14 years of cattle grazing before the exclosure was built.

The exclosure was part of the “Range Condition and Trend” project undertaken to monitor recovery after the 1960s drought (Foran 1973a). Intensive study at the site throughout the 1970s showed few consistent impacts attributable to cattle grazing (Foran et al. 1982). The exclosure was originally 3.2 km extending to near Spinifex Bore (Figure 4), but was subdivided in 1982 in a verbal agreement with the former owners of Mt Riddock. The area adjacent to the bore has since been used as a holding paddock. The sampling location markers, as described by Foran (1973b), were removed from the grazed area around this time.

The exclosure was found intact in the late 1990s, and obvious visual differences in pasture composition had developed. While the limitations of non-replicated exclosure treatments are acknowledged (for example, Valamanesh 1999), the size of the exclosure and the length of time the treatments had been in place warranted investigation and documentation. In particular, it was noted that *Eragrostis eriopoda*, a long lived perennial grass, appeared to have increased under grazing while palatable annual grasses like *Enneapogon polyphyllus* and *Aristida contorta* were more common inside the exclosure. It was also noted that there were very few 'soft' spinifex tussocks, *Triodia schinzii*, in the grazed area. The palatable shrub, *Rhagodia eremaea*, appeared to be more abundant inside the exclosure, but was also common in the grazed area. These and other observations were quantified and are documented in this Technical Bulletin.

2. METHODS

2.1. Site Description

The study area is located on a sparsely timbered, sandy plain of coarse-textured alluvium derived from the nearby Harts Range (Perry et al. 1962). The vegetation comprises very scattered low trees and shrubs (*Acacia estrophiolata*, *A. aneura*, *A. kempeana, Atalaya hemiglauca*, *Ventilago viminalis,* and *Hakea* spp.) over pasture dominated by kerosene grass (*Aristida holathera*) and woollybutt *(Eragrostis eriopoda*). There is a median yearly rainfall of 259 mm (1949-2001), but with substantial variation between years (Figure 2). The only time fire has burnt the study location was in December 1976, after a tremendous build up of fuel over several wet years, clearly shown in Figure 3.

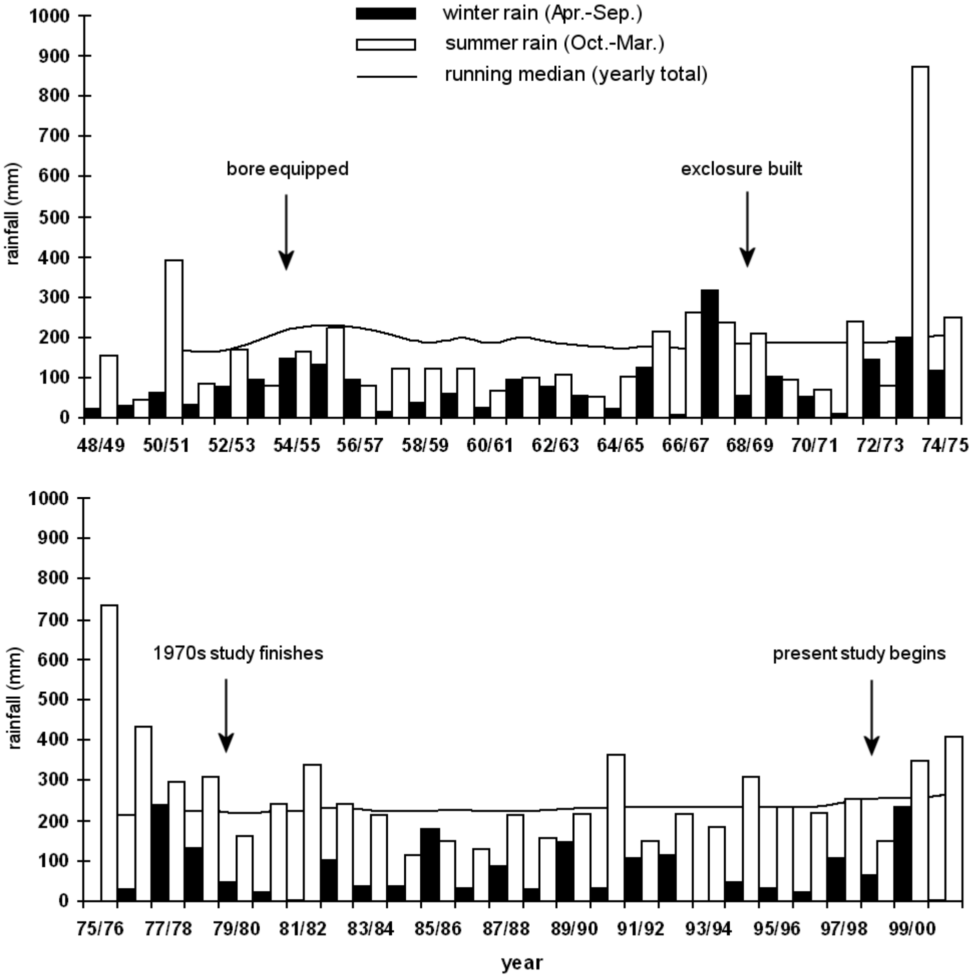

Figure 2. Time line of important events and rainfall at Spinifex bore. Summer (October - March) and winter (April - September) rainfall totals and running median yearly rainfall (1949-2001) for Harts Range Police Station, located 5 km from the study site. Source: NT Monthly Weather Review. Bureau of Meteorology

Figure 3. Vegetation flux masked grazing impacts in the early years of Spinifex bore exclosure. Substantial rainfalls occurred at this photo point inside the exclosure between 1973 and 1976. The 1973 photograph shows kerosene grass (*Aristida holathera*) with scattered woollybutt (*Eragrostis eriopoda*) tussocks, and a single feathertop spinifex (*Triodia schinzii*) clump in the mid-ground. The 1976 photograph shows a thick ground cover hidden under the growth of the tall forbs, verbine (*Cullen patens*) and bird flower (*Crotalaria cunninghamii*). Fire burnt the exclosure five months after the 1976 photograph was taken, but is not known to have occurred since.

The study location comprises the exclosure (0.8 km x 1.6 km), and two adjacent grazed strips (0.4 km x 1.6 km), on each side of the exclosure (Figure 4). There is only low relief over the study area, comprising minor dunes and swales with no distinct drainage pattern, so stratification was not required. Site uniformity was probably a factor in the original placement of the exclosure.

2.2. Pasture Sampling

A 100-m x 100-m grid was used to randomly choose eight sites from a possible 12 in each of five blocks, also randomly chosen, from a possible eight (Figure 4). The sampling layout was designed to facilitate averaging of data to either site level or block level, depending on what would be required to meet the requirements for statistical analyses. The 40 sites were located in the field and a 10-m x 10-m grid was established north and east of a site marker post. Twenty 1 m^2 quadrats (sampling plots) were randomly allocated among the 100 positions available at each site. In total, 800 sampling plots were marked for relocation using 250-mm deck-spikes driven into the ground in the south east corner of each sampling plot, each with a numbered aluminium-plate tag attached.

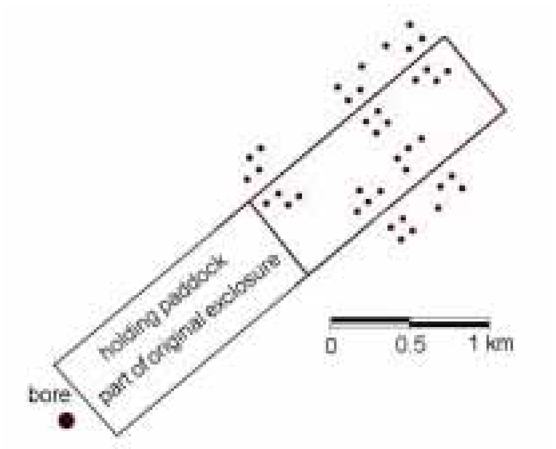

Figure 4. Spinifex bore exclosure, showing distance to the bore and original exclosure size. Black dots indicate location of sampling sites, each comprising 20 sampling plots.

In each sampling plot, dry matter weight of each species present was visually estimated, thus also providing data on frequency of occurrence. Visual estimates were assisted by site-specific photo-standards of known botanical composition and dry matter production (Friedel and Bastin 1988, Wilkie 1997). Visual estimates were further calibrated by estimating, and then harvesting and drying a range of sampling plots adjacent to a site before, during, and after each sampling event. This data was used to check consistency of operator estimates between years. The same operator made the visual estimates in 2000, 2001, and for 60 percent of sites in 1998.

The perennial tussock grass, *Triodia schinzii* (feathertop spinifex) was estimated for dry matter production only once, in 2000, because its growth tends to be slow and cumulative, more like a shrub.

2.3. Timing of Sampling

Sampling events were timed to coincide with maximum productivity following significant falls of rain (Figure 5). In 1998, there was 90 mm of rain in April, six weeks before sampling, while in 2000 there was abundant rainfall, with 221 mm of rain in April, six weeks before sampling. Good seasonal conditions continued into 2001, when 100 mm of rain was recorded three months in a row over the summer, and was followed by 65 mm of rain in March, nine weeks before sampling.

Although it is difficult to account for short-term pasture utilisation in an uncontrolled grazing experiment such as this, the presence of cattle was noted on each visit. Evidence of cattle grazing in the form of chewed tussocks was also noted when observed at sampling sites. Potential errors associated with timing of sampling and short term grazing utilisation are described further in the discussion section.

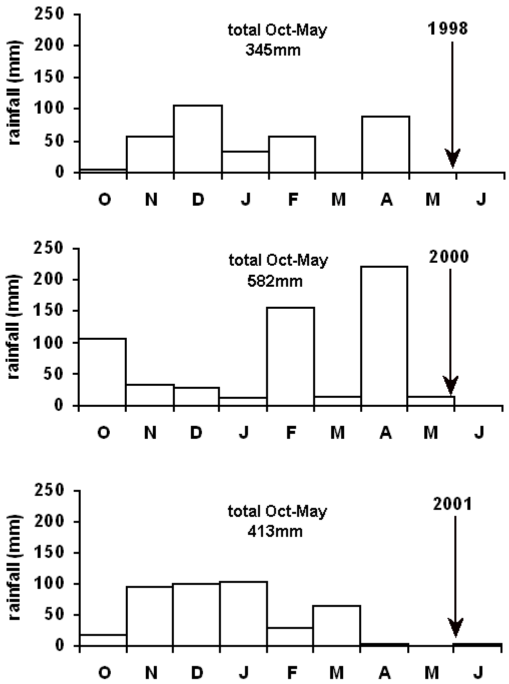

Figure 5. Monthly rainfall over the summer/autumn period (October - March) leading up to sampling events in 1998, 2000, and 2001 at Spinifex bore exclosure. Sampling timing is shown by the vertical arrow.

2.4. Trees and Shrubs

In 1998, at each sampling site, the Bitterlich gauge method was used to estimate percentage canopy cover for all tree and shrub species (Friedel and Chewings 1988). The average percentage canopy cover from each treatment block of four sites was compared for the six trees or shrubs with highest overall estimated canopy cover.

2.5. Data Analysis

Dry matter production data was only considered for those species that contributed more than one percent of total estimated yield during both treatments in any sampling year. Individual 1 m^2 sampling plots were combined and their data averaged until the assumptions for a one way analysis of variance were met, based on Bartlett's test for homogeneity of variances in Genstat 5™ (copyright Lawes Agricultural Trust 1998). For those species considered in this analysis, all data from 2000 and 2001 were suitable at the 10 x 1 m^2 (half-site) level, after natural log transformation and the addition of a small positive value in some cases. *Aristida holathera* and total pasture yield data did not require transformation. Most of the 1998 data was also suitable for analysis of variance when averaged to 10 x 1 m^2 plots. However, three data sets had to be further averaged to the 20 x 1 m^2 (site) and 40 x 1 m^2 (half-block) levels.

Frequency of occurrence was analysed for all species based on presence or absence in 10 x 1 m^2 - combined sampling plots (half-site level). This level of combination of sampling plots was chosen to improve some of the limitations of frequency data. At the site level (20 x 1 m^2), common species will have the same value recorded as single occurrences of plants which may cause uncommon plants to be over-represented. At the sampling plot level (1 x 1 m^2), a dense stand of a particular species at one site could skew data for the whole treatment. By combining 10 x 1 m^2 sampling plots, common plants have the chance to be recorded twice at a physical sampling site, while single occurrences of species at a site are less likely to be over-represented in abundance. Frequency data was analysed using (2 x 2) contingency tables (*n=80*) and Fisher's exact test in Genstat 5™. The number of pasture species in 20 x 20 m^2 samples from each treatment was compared using means and standard error of means, while mean percentage crown covers of trees and shrubs were also compared.

3. RESULTS

3.1. Estimated Dry Matter Production

Average dry matter estimates for the four dominant pasture grasses are shown in Figure 6, while Table 1 shows average dry matter estimates for all species contributing greater than one percent of total pasture production in each sampling year. The data shows several highly significant ($p<0.001$) differences between grazing treatments and, for three grass species, these differences were recorded at all sampling events. *Enneapogon polyphyllus* and *Aristida contorta* consistently had higher estimated production inside the exclosure, while *Eragrostis eriopoda* had consistently higher estimated production in the grazed treatment. These differences were very large, with for example, *E. polyphyllus* having 17 times greater estimated production inside the exclosure after two consecutive wet seasons.

Of the other common species, *Aristida holathera* was consistently unaffected by grazing treatment ($p>0.05$), while various other grasses and forbs showed significant differences between treatments when seasonal conditions were favourable. In 1998, both *Bonamia media* and *Tribulus terrestris*, two ground covering forbs, had significantly higher estimated production inside the exclosure. After two consecutive wet seasons, the tall forbs, *Crotalaria cunninghamii* and *Cullen patens*, became significant contributors to estimated production, with no difference between treatments.

A spectacular increase inside the exclosure, during the exceptional conditions of 2000, was in the short-lived forb *Salsola kali*, producing an estimated 333 kg ha^{-1} of dry matter, with only 2 kg ha^{-1} being recorded in the grazed treatment. The forb *Sida rohlenae* had significantly higher estimated production in the grazed area during 2000 and 2001.

The 'spinifex' grass, *Triodia schinzii,* contributed an average of 100 kg ha^{-1} dry matter to the pasture inside the exclosure when estimated in 2000, with no specimens being recorded in the grazed treatment. This extra 100 kg ha^{-1} could be added to the total estimated yield data for the exclosed treatment in both 1998 and 2001, because of the stability of this feed. Table 1 does not show this however, as it would have made no difference to the analysis of variance for total estimated yield in 1998 and 2001. Only in 2000, because of the contribution of *Salsola kali*, was there a significant difference between treatments for total estimated yield.

Another species, recorded only in one treatment, was *Eriachne aristidea*, an unpalatable grass, which increased estimated production over two wet seasons in the grazed area only.

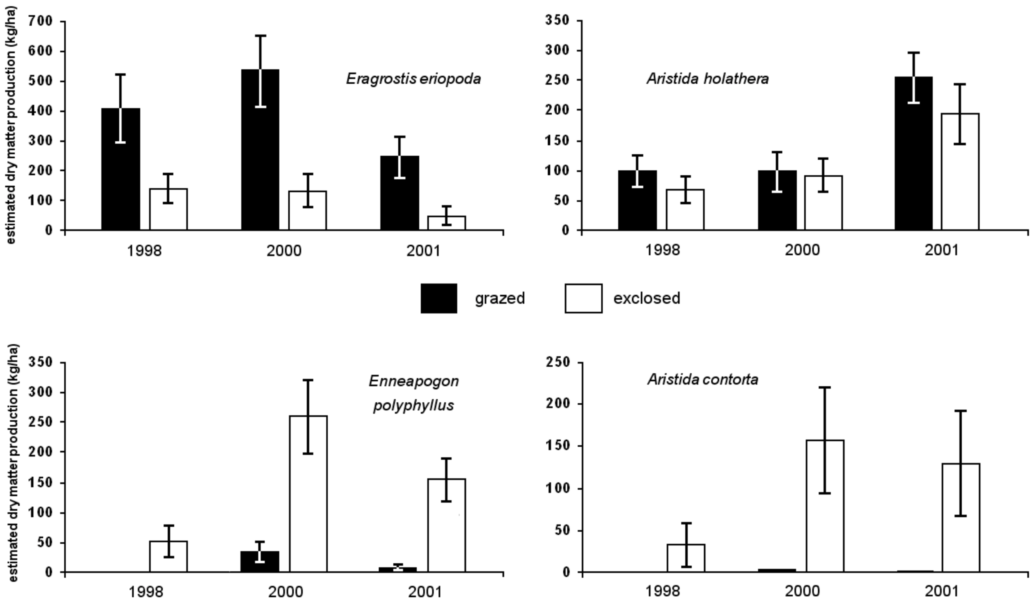

Figure 6. Average estimated dry matter production (kg ha-1) and standard errors of the means for four dominant pasture grasses at Spinifex bore cattle exclosure. Differences between treatment and sampling year are shown.

Table 1. Average estimated dry matter production (kg ha^{-1}) and standard errors of means between treatments for all species contributing greater than one percent of total pasture yield at Spinifex bore cattle exclosure. Probability values, replications and degrees of freedom used in analysis of variance are also shown.

	grazed		exclosed		*p value*	*rep(df)*
1998						
Total estimated yield	570	*±57*	404	*±25*	*0.057*	*10(18)*
Aristida contorta	<1		33	*±10*	*<0.001*	*10(18)*
Aristida holathera	99	*±13*	68	*±11*	*0.061*	*40(78)*
Aristida latifolia	4	*±2*	17	*±10*	*0.954*	*40(78)*
Enneapogon polyphyllus	1	*±1*	51	*±10*	*<0.001*	*20(38)*
Eragrostis eriopoda	409	*±57*	139	*±24*	*<0.001*	*40(78)*
Bonamia media	6	*±1*	34	*±7*	*<0.001*	*40(78)*
Tribulus terrestris	3	*±1*	22	*±4*	*<0.001*	*40(78)*
2000						
Total estimated yield	714	*±60*	1089	*±59*	*<0.001*	*40(78)*
Aristida contorta	3	*±1*	158	*±31*	*<0.001*	*40(78)*
Aristida holathera	99	*±16*	92	*±13*	*0.748*	*40(78)*
Enneapogon polyphyllus	34	*±9*	260	*±30*	*<0.001*	*40(78)*
Eragrostis eriopoda	535	*±59*	133	*±27*	*<0.001*	*40(78)*
Salsola kali	2	*±1*	333	*±45*	*<0.001*	*40(78)*
Sida rohlenae	41	*±6*	5	*±1*	*<0.001*	*40(78)*
Triodia schinzii	0		109	*±59*		
2001						
Total estimated yield	634	*±41*	598	*±40*	*0.522*	*40(78)*
Aristida contorta	2	*±1*	130	*±31*	*<0.001*	*40(78)*
Aristida holathera	254	*±21*	194	*±24*	*0.064*	*40(78)*
Enneapogon polyphyllus	9	*±2*	155	*±17*	*<0.001*	*40(78)*
Eragrostis eriopoda	247	*±35*	50	*±14*	*<0.001*	*40(78)*
Eriachne aristidea	35	*±10*	0			
Crotalaria cunninghamii	23	*±9*	10	*±4*	*0.176*	*40(78)*
Cullen patens	41	*±11*	57	*±15*	*0.969*	*40(78)*
Sida rohlenae	25	*±3*	2	*±1*	*<0.001*	*40(78)*

3.2. Frequency of Occurrence

The annual grasses, *Enneapogon polyphyllus* and *Aristida contorta*, and perennial grasses, *Panicum decompositum* and *Triodia schinzii*, were significantly ($p<0.05$) less frequent in the grazed treatment on all sampling occasions (Table 2). The perennial grass, *Eragrostis eriopoda*, and the forbs, *Sida rohlenae*, *Sida cunninghamii*, and *Tephrosia sphaerospora*, were significantly more frequent in the grazed area on all sampling occasions.

There were 12 species of annual grasses and forbs with significant differences in frequency between treatments for short periods when seasonal conditions were favourable for their growth. In 1998, the forbs, *Tribulus terrestris, Bonamia media*, *Evolvulus alsinioides*, and *Trachymene glaucifolia*, all had significantly higher frequencies in the exclosed treatment, while *Sida platycalyx*, and the annual grass, *Dactyloctenium radulans*, had significantly higher frequencies in the grazed treatment. In 2000, the forbs *Bonamia media* and *Salsola kali*, were more frequent in the exclosed treatment, while the grasses, *Dactyloctenium radulans*, *Urochloa gilesii*, and *Eriachne aristidea*, were all significantly more frequent in the grazed treatment. For *Eriachne aristidea* and *Salsola kali*, the differences from 2000 persisted into 2001.

There were 15 pasture species with no significant difference between treatments at any time (Table 2). This group includes two annual grasses, five perennial grasses, and eight forb species. Some forbs such as *Goodenia mitchellii* had similar frequencies across treatments in all sampling years, while others like *Ipomoea polymorpha* became frequent across both treatments for a short time only.

Table 2. Frequency of occurrence of pasture species at Spinifex bore cattle exclosure based on species presence or absence in 40 x 10 m^2 samples from each treatment (grazed and exclosed). Significance and direction of differences based on Fishers exact test in Genstat 5 (p<0.001***, p<0.01**, and p<0.05*).

Species with a persistent significant difference in frequency

treatment	Grazed 1954 - present			Exclosed 1969 - present		
year	*1998*	*2000*	*2001*	*1998*	*2000*	*2001*
Annual grasses						
Enneapogon polyphyllus	10	26	22	31***	40***	40***
Aristida contorta	4	9	6	19***	31***	32***
Perennial grasses						
Eragrostis eriopoda	40**	40**	38*	31	32	29
Panicum decompositum	1	2	7	9*	18***	23***
Triodia schinzii	0	0	0	6*	6*	6*
Forbs						
Sida cunninghamii	21*	26*	22***	10	16	7
Sida rohlenae	31**	38**	37***	17	27	16
Tephrosia sphaerospora	29*	21**	16**	18	8	4

Species with a significant difference in frequency after favourable seasonal conditions

treatment	Grazed 1954 - present			Exclosed 1969 - present		
year	*1998*	*2000*	*2001*	*1998*	*2000*	*2001*
Annual grasses						
Urochloa gilesii	4	13***	7	3	1	2
Dactyloctenium radulans	14***	25***	0	0	0	0
Eriachne aristidea	5	18***	21***	1	1	1
Triaphris mollis	0	5	10*	0	2	2
Forbs						
Bonamia media	21	6	17	36***	24***	19
Trachymene glaucifolia	2	0	0	18***	7*	5
Tribulus terrestris	20	0	2	36***	0	2
Salsola kali	1	5	1	1	38***	36***
Sida platycalyx	20***	24***	0	5	7	0
Indigofera colutea	10	35**	16	4	22	10
Evolvulus alsinioides	4	22	8	17**	18	15
Cleome viscosa	1	14*	2	0	5	1

Species with no significant differences in frequency

treatment	Grazed 1954 - present			Exclosed 1969 - present		
year	*1998*	*2000*	*2001*	*1998*	*2000*	*2001*
Annual grasses						
Aristida holathera	40	40*	40	38	34	40
Perotis rara	2	5	2	0	1	0
Perennial grasses						
Chrysopogon fallax	6	8	7	7	7	6
Aristida latifolia	6	5	4	5	5	6
Digitaria brownii	0	0	0	1	1	1
Digitaria coenicola	0	0	0	1	4	4
Cenchrus ciliaris	1	1	4	0	1	1
Forbs						
Calotis hispidula	33	0	0	27	0	0
Cullen patens	14	18	21	23	16	19
Crotalaria cunninghamii	0	1	15	0	3	9
Goodenia mitchellii	15	15	19	18	18	22
Ipomoea polymorpha	39	0	0	34	0	0
Melhania oblongifolia	7	15	0	9	12	0
Othonna gregorii	29	0	0	31	0	0
Swainsona phacoides	36	2	0	35	10*	0

3.3. Pasture Species Diversity

The mean number of species identified in each of 20 x 20 m^2 samples is shown in Figure 7, along with the range, as standard errors of means were very small for these data. Analysis of variance confirmed there was no significant difference in number of species sampled at the 5% level for any year. Figure 7 also shows that the number of species comprising the pasture declined during the study period. The mean number of species in a 20 m^2 sample over both treatments was 24 in 1998, declining to 15 in 2000, and 12 in 2001. Frequency and estimated dry matter production data confirm that a few grasses became predominant at the expense of a variety of short-lived forbs.

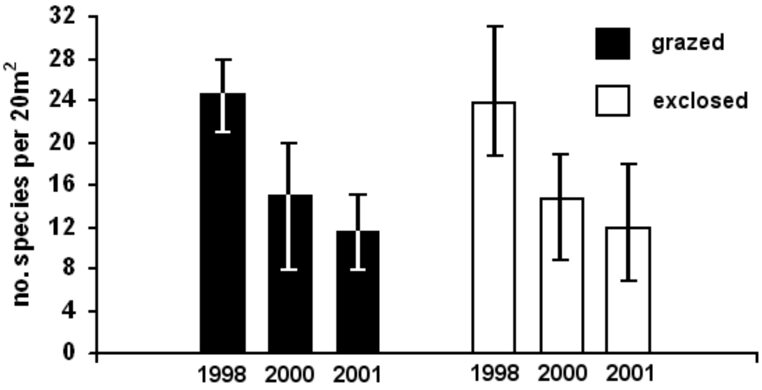

Figure 7. Mean number of pasture species, and range of values recorded in 20 x 20 m^2 samples from each treatment in each sampling year at Spinifex bore cattle exclosure

3.4. Trees and Shrubs

Overall, estimated percentage canopy cover was very low, at all times staying below one percent of total surface area. Average percentage canopy cover for all species was 0.7 percent and 0.5 percent for the exclosed and grazed treatments, respectively. The only woody species to show a consistent difference between treatments was the chenopod shrub, *Rhagodia eremaea*, which had more than twice the canopy coverage in the exclosed treatment over all blocks (Figure 8). Three treatment blocks had even greater magnitudes of difference indicating that any coverage data collected for this species is likely to produce significantly different results. It was also noted that *R. eremaea* still had the highest canopy coverage of any woody species in the grazed treatment, and that it was distributed relatively evenly across all treatment blocks.

Other species produced skewed data and no consistent trend over all treatment blocks. The effect of small thickets of shrubs can be seen in Figure 8 for broombush (*Senna artemisioides* subsp. *nemophila*) and witchetty bush (*Acacia kempeana*). The important fodder and shade tree, supplejack, *Ventilago viminalis*, occurred consistently across each block inside the exclosure, but was not recorded in two of the five blocks in the grazed treatment. An analysis of variance on *Ventilago viminalis* suggested a non-significant result ($p>0.05$) would be obtained from this data, probably due to the higher canopy cover in the grazed area of treatment block number two.

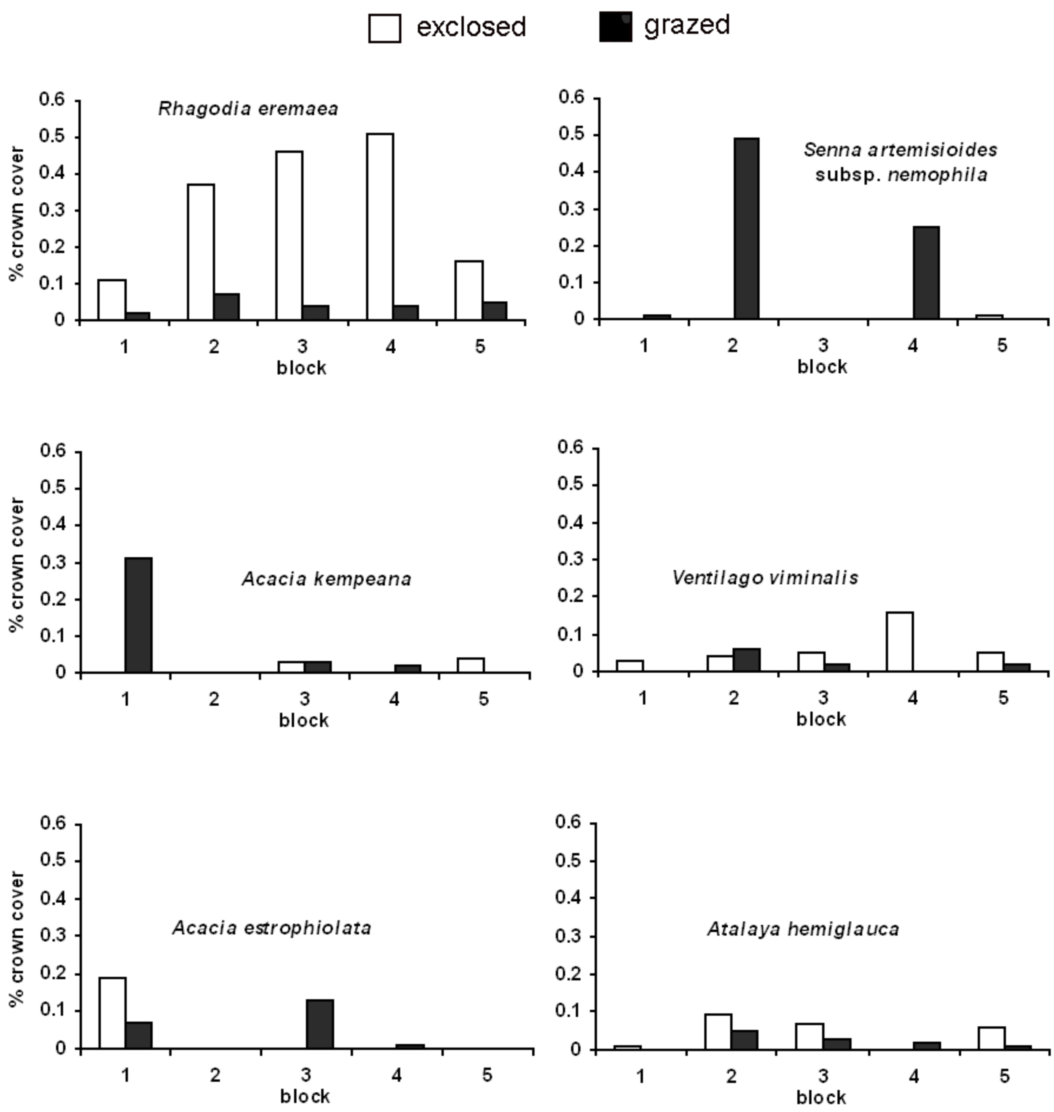

Figure 8. Estimated percentage canopy crown cover of six common woody species at Spinifex bore cattle exclosure, 1998, as derived by the Bitterlich variable plot method. Percentage canopy cover shown for each of five blocks, with each block being an average value of four sites within each treatment, grazed and exclosed.

4. DISCUSSION

4.1. Pasture Sampling

The use of photo-standards of known botanical composition and yield were useful for training and for getting started after breaks from data sampling. However, they were awkward to use in the field and it was difficult to continually change focus from the scale of the photographs to the scale of the ground.

The results of visually estimating and harvesting, drying, and weighing a range of 1 m^2 calibration plots are shown in Figure 9. Similar correlation coefficients were obtained in each sampling year, indicating that differences between years are not likely to have been greatly affected by operator bias. Figure 9 does show there was a tendency to underestimate dry matter weights in 2000, largely in the range 25 g/m^2 to 75 g/m^2, which affected the correlation coefficient for that year. Overall, a general linear relationship between estimated and actual dry matter was demonstrated.

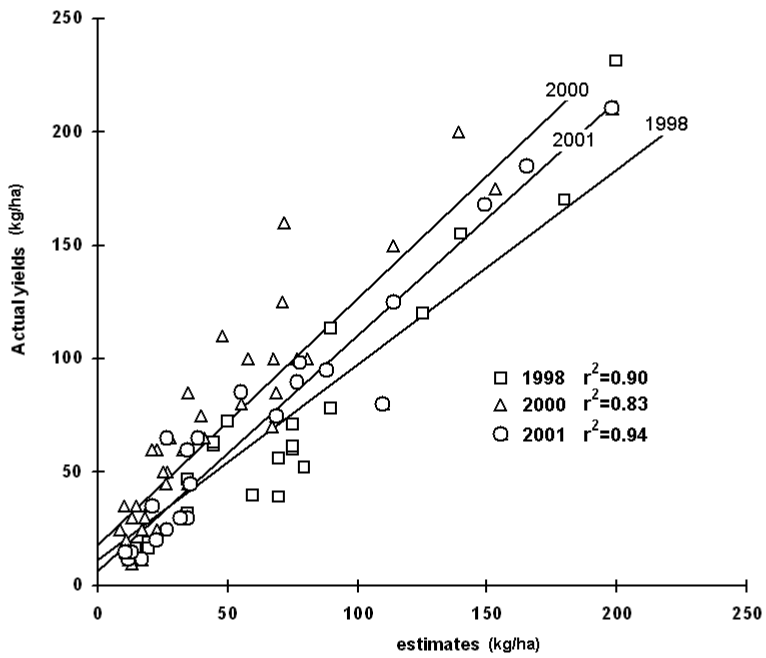

Figure 9. Scatter plots of estimated versus actual pasture yields (kg ha^{-1}) taken from 1 m^2 calibration plots at Spinifex bore in each sampling year. Slope and y-intercept of line of best fit is shown for each sampling year along with the correlation coefficients (r^2)

4.2. Timing of Sampling

The 1998 results may have been affected by seasonal conditions the previous year. Good summer rains occurred in January and February 1997, which would have germinated *Enneapogon polyphyllus* across both treatments. Those plants inside the exclosure may have persisted into 1998, remaining intact and reviving after small falls of rain. *E. polyphyllus* plants in the grazed area may have been depleted through grazing, trampling and disintegration over 12 months or so, but with not enough suitable rain for new plants to germinate.

The 2000 results are perhaps the most sound, as sampling was done at a time of near-maximum productivity, following good rains in February and record monthly rainfall in April.

The 2001 results may have been affected by sampling more than two months after the last significant rainfall. There was some evidence of grazed and pulled grass tussocks at this time. *Enneapogon polyphyllus* decreased in frequency of occurrence between 2000 and 2001 by 15 percent in the grazed treatment but remained unchanged inside the exclosure. During the same period, estimated production for this species dropped by 74 percent and 40 percent, respectively. This suggests that perhaps at least some of the yield decline of *E. polyphyllus* in the grazed treatment between 2000 and 2001 may have been due to cattle utilisation.

Short-term cattle utilisation is a potential source of error, particularly for estimated dry matter production data. However, the consistent and highly significant differences for various species between treatments, under various seasonal conditions, suggests that recent cattle grazing was not an important factor affecting overall results or conclusions of the study.

4.3. Comparison with Results of the 1970s

It was not possible to exactly repeat the 1970s study as the site marker posts had been removed from the grazed treatment. Time efficiency has also been a factor in superseding some aspects of the methods employed (Friedel and Shaw 1987). In the 1970s study, after establishing the sampling infrastructure of 36 transects, it was estimated to take 60 hours on each subsequent visit to complete the pasture measurement aspects of the sampling (Foran 1973b). After establishing the 40 sites for the present study, it took increasingly less time to complete field data collection each sampling year. In 1998, data was recorded onto paper and entered into a computer afterwards, while in 2000, estimates were relayed using two-way radio to a second operator entering data directly to a computer in the field. In 2001, voice recognition technology reduced labour requirements to one operator with automated data entry, while reducing field time to around 25 hours.

The most suitable data from the 1970s study in terms of comparison with the current results, is perhaps the pasture yield data - the result of harvesting 180 x 1m^2 plots in each sampling year over both treatments. These results, some of which are reported in Foran et al. (1982), describe a very different pasture composition to that presented in this Technical Bulletin. Foran et al. (1982) do not mention the now dominant pasture species, *Eragrostis eriopoda*, or the annual grasses, *Enneapogon polyphyllus* and *Aristida contorta*. *Aristida holathera* however, was the dominant species during the 1970s, comprising up to 86% of total pasture production between 1974 and 1978. During the present study, *A. holathera* made up 17% of total pasture in 1998, with 11% and 36% in 2000 and 2001, respectively. It appears that *A. holathera*; although tending to increase during consecutive 'wet' years, did not regain the dominance in 2000 and 2001 that it had throughout the 1970s.

To find out about the other three grass species, some original computer printouts of the 1970s data analyses were examined. These data showed that *Eragrostis eriopoda* was scarce, contributing an average of 17 kg ha^{-1} or less than two percent of total pasture yield between 1973 and 1978 over both treatments (Figure 10). By comparison, between 1998 and 2001, *E. eriopoda* contributed 252 kg ha^{-1} or 38 percent of total pasture yield over both treatments. Figure 10 also shows that *Enneapogon polyphyllus* and *Aristida contorta* were minor components of the pasture during the 1970s. Both species combined contributed an average of 11 kg ha^{-1} or two percent of total pasture over all sampling years. Furthermore, Figure 10 does not show any obvious or consistent differences between treatments for any of these pasture grasses during the 1970s.

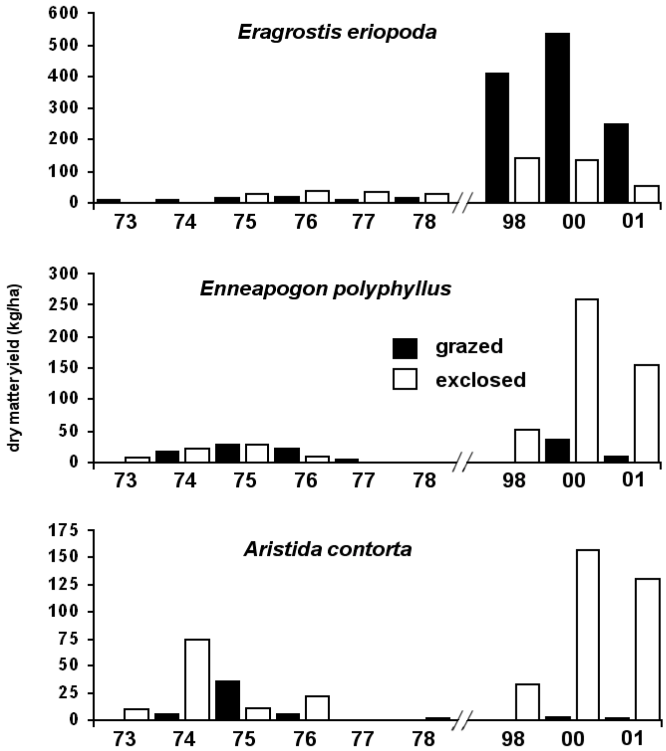

Figure 10. Comparison of dry matter production for three grass species during the 1970s, and in 1998-2001, at Spinifex bore cattle exclosure. Mean dry matter production is based on 180 x 1 m^2 harvested sampling plots in each year of the 1970s (Foran 1973b), and 800 x 1 m^2 visually estimated sampling plots in 1998-2001.

It would appear that *E. polyphyllus* and *A. contorta* are at roughly similar levels in the grazed treatment today as they were across both treatments in the 1970s. However, both species have dramatically increased their dominance of the ungrazed pasture since that time. *E. eriopoda* has greatly increased its dominance over both treatments since the 1970s, but with a much larger increase in the grazed area.

Total pasture yield peaked in the present study during 2001, when an average of 1,089 kg ha^{-1} was recorded inside the exclosure (901 kg ha^{-1} across both treatments). This is lower than was recorded from 1974 to 1976 during exceptional seasonal conditions, peaking at 1,870 kg ha^{-1} in 1975. The only relatively 'dry' year of the 1970s study (1973) had an average of 550 kg ha^{-1} dry matter production, which compares with 1998 (487 kg ha^{-1}) and 2001 (616 kg ha^{-1}). Total productive potential of pastures appears not to have changed much at Spinifex bore, being highly dependent on rainfall; but pasture composition is very different between and across treatments after another two decades of the imposed treatments, grazed and exclosed.

4.4. Eragrostis eriopoda

The results suggest that grazing can sometimes increase abundance and productivity of the long-lived perennial grass, *Eragrostis eriopoda*. This species is widespread in Australian rangelands, surviving consistent stocking, and providing low quality forage after less hardy plants are removed by grazing (Lazarides 1970). Even so, it has been found to decrease under grazing in some circumstances (Landsberg et al. 1997). It has been reported to increase in density in holding paddocks in Western Australia (Mitchell and Wilcox 1994).

Although not directly comparable, the 1970s data from Spinifex bore exclosure strongly indicates that *E. eriopoda* has greatly increased in abundance under grazing since that time.

In terms of landscape stability, increased production and frequency of *E. eriopoda* tussocks at Spinifex bore under grazing may have created a land surface even more resistant to wind and water erosion than ungrazed land. The 1958-1966 drought which partly initiated the construction of the Spinifex bore exclosure was characterised by widespread erosion exacerbated by over-utilisation of poor quality soil binding grasses like *E. eriopoda* and other coarse feeds in the district (Condon et al. 1969). This is unlikely to occur again because current drought management involves progressive de-stocking rather than utilising poorer and poorer feeds. It is likely that *E. eriopoda* tussocks would be left mostly ungrazed during any future extended drought when wind erosion has most potential. Water erosion following drought-breaking rains is also less likely if substantial numbers of *E. eriopoda* tussocks can persist through a long drought period.

4.5. Enneapogon polyphyllus

E. polyphyllus, along with *E. avenaceus*, are important contributors to central Australia's ability to quickly fatten cattle when good seasons occur. They are widespread, short-lived, annual or biennial grasses, which respond quickly to summer rainfall and which can persist while seasonal conditions are favourable. Both species are important in open woodland pastures, with *E. polyphyllus* also being an important pasture species in some mulga and spinifex vegetation, while *E. avenaceus* extends to various calcareous land types in the region. These oat grasses are therefore common in nearly every important pastoral land type of central Australia.

Previous studies have shown that *E. avenaceus* can be less abundant close to water points (Friedel 1997), and that its density can fluctuate considerably, but with greater increases and higher densities occurring in ungrazed treatments (Grice and Barchia 1995). Adequate seed replenishment of *E. avenaceus* has been shown to be optimal in paddocks where 60% or more of the plants are ungrazed or only lightly defoliated (Bosch and Dudzinski 1984).

Phillips et al. (2001), in a grazing trial 50 km from the Spinifex bore study site, and conducted over the same time period, found that *E. polyphyllus* was heavily utilised by grazing livestock. Up to 98% of comparable biomass available in an ungrazed control paddock was utilised in a grazed paddock during a short but severe drought in 1999. Even after consecutive good seasons, the stocked paddocks had less than 20% of the *E. polyphyllus* biomass available in the ungrazed control paddock. However, it was also reported that after consecutive good seasons, the frequency of occurrence of *E. polyphyllus* was similar across all treatments indicating that seed reserves were intact. It was observed that ungrazed plants were able to persist and continue growing during extended good seasons, and this accounted for substantial differences between treatments for estimated productivity. Under grazing, regrowth following periodic rains was more exclusively from new seedlings. In the study by Phillips et al, (2001), there were indications that, given good rains, the potential for recovery of *E. polyphyllus* under grazing was intact. In the present study at Spinifex bore, however, frequency results showed that *E. polyphyllus* did not recover under grazing, given the same good rains.

The present study has documented a highly significant consistent difference in the abundance and estimated productivity of *E. polyphyllus* under grazing in one land type. There is now a considerable body of quantitative and observational evidence that *Enneapogon* spp. can decrease under grazing in various land types of central Australia. Despite this, there has been little research and no field trialling of what grazing strategies may slow or reverse this decline. It is generally suggested that resting country from grazing during active growth periods can replenish seed reserves of *Enneapogon* spp. (Bastin 1996; 1998). However, there is no information on the time frames involved in a spelling regime aimed at maintaining *Enneapogon* spp. in a pasture. At Spinifex bore, significant differences in production of *E. polyphyllus* as a result of spelling had not occurred after 10 years, even with good seasonal conditions. However, after 30 years of spelling, highly significant increases of *E. polyphyllus* had developed.

The widespread occurrence of these plants after general rains may ensure their seed replenishment in many cases because stocking rates tend to be aligned with drier conditions when less pasture is available. Nevertheless, because the oat grasses are of considerable importance to the central Australian beef cattle industry, there should be more research on aspects of its ecology under grazing. This may lead to the implementation of grazing strategies that can maintain or even increase these plants as a component of grazed pastures.

4.6. Other Species

Aristida contorta is very widespread over inland Australia and is regarded as moderately palatable and a useful feed when green. It dries out quickly, lacking the bulk and persistence of *E. polyphyllus*. Landsberg et al (1997) considered it as an 'increaser' species at two out of three grazing gradients in mulga in which it occurred. Mitchell and Wilcox (1994), in Western Australia, consider it to have little value as a rangeland condition indicator species.

Although a widespread species in mulga and open woodland vegetation types, *A. contorta* was a minor component of the grazed sandy open woodland studied here. However in the ungrazed treatment, it contributed as much as 20% of available pasture after consecutive wet years. Estimated yield was 65 times greater in the ungrazed treatment at this time. In these particular sandy open woodlands, *A. contorta* might be considered a 'decreaser' species, with its presence indicating good rangeland condition.

Salsola kali became dominant after good rains in 2000, but in the exclosed treatment only, suggesting that cattle were either grazing the seedlings as they emerged, or that grazing over time has depleted the seed bank for this species. It is generally regarded as palatable to cattle only when young and green (Cunningham et al. 1992; Mitchell and Wilcox 1994; Bohning and Wilkie 1999).

Triodia schinzii was absent from the grazed treatment, but was encountered in 15 percent of samples inside the exclosure. Presumably, the naming of the water point around 1954 suggests that it was common in the area at that time. Individual plants were found in the grazed area by searching further afield, but they were uncommon and were invariably well grazed. This spinifex grass is well developed on the sand plains in the northern half of central Australia, occurring as the dominant species over extensive areas. It extends to the Pilbara coast in Western Australia, where it is a valuable carry-over fodder in the dry season (Stretch 1996). In central Australia, it seems that where *T. schinzii* is dominant on extensive sand plains, its pastoral value is low. However, where it occurs associated with 'open woodlands of mulga' (Lazarides 1970), it is a preferred pasture species for grazing cattle. Soil fertility is the most probable factor affecting its pastoral potential in different range types.

Some minor species, like the palatable annual grasses, *Urochloa gilesii* and *Dactyloctenium radulans*, had significantly higher frequency of occurrence at times in the grazed area; a result that might be unexpected, given their high palatability (Bohning and Wilkie 1999). These species seem to have been favoured by disturbance of the soil by cattle under tree and shrub canopies.

4.7. Trees and Shrubs

The only difference identified for woody vegetation in the study was that canopy cover of the chenopod shrub, *Rhagodia eremaea*, was consistently higher inside the exclosure. However, it also had the highest canopy cover of any woody plant in the grazed treatment. Part of this canopy difference may be explained by cattle keeping shrubs in the grazed treatment trimmed back. Most large trees in both treatments had a scattering of *R. eremaea* underneath their canopy area, including those where cattle rest during the day. The shrubs in the grazed treatment were compact and 'leafier' from regular browsing, whereas the shrubs inside the exclosure were woody and spreading, creating bare soil underneath.

The 'Bitterlich' variable plot method used to collect data on percentage canopy cover by species was an easy and efficient method for sampling the woody plant population. It was limited though, in that important parameters such as age class structures of different species were not measured. In particular, it would be valuable to estimate the population age structure of supplejack (*Ventilago viminalis*) trees, to ensure that this valuable pastoral tree is regenerating adequately under grazing. Similarly it is not possible to tell, using the 'Bitterlich' method, if the canopy differences reported for *Rhagodia eremaea* are the result of reduced canopy cover from cattle browsing, or actually reflect a difference in abundance of individual plants.

The widely scattered, but often clumped, woody vegetation typical of open woodlands makes collecting tree and shrub data suitable for standard statistical tests difficult. Figure 11 shows the very scattered distribution of woody vegetation at the Spinifex bore study location, while also showing a clumping effect, where a whitewood (*Atalaya hemiglauca*) has emerged from under the canopy of a supplejack (*Ventilago viminalis*) tree. Older trees become focal points for recruitment of other species, particularly for bird-dispersed species such as *Rhagodia eremaea*. Non-random spatial patterns of woody vegetation make it difficult to obtain an adequate sample suitable for statistical analysis, given available human resources. It seems that there is still considerable scope for developing methods of collecting data from tree and shrub populations, other than for canopy cover, in these open woodlands.

Figure 11. Looking south-east across the exclosure treatment, Spinifex bore 1970 and 1997, showing scattered low trees over woollybutt (*Eragrostis eriopoda*) and kerosene grass (*Aristida holathera*). The tree in the left-hand mid-ground in both views is a supplejack (*Ventilago viminalis*), while several whitewoods (*Atalaya hemiglauca*) in the mid-background, and berry saltbushes (*Rhagodia eremaea*) in the foreground, have become prominent in the 1997 photograph. Note the young whitewood emerging through the canopy of the mature supplejack tree

4.8. Sustainability of Grazing

The differences in pasture composition which have developed over three decades at Spinifex bore involve shifts in dominance of individual species, rather than a reduction in species diversity or of pasture biomass being produced. Nearly all species have been able to persist under grazing, but estimated productivity of some important species has been substantially suppressed, while other species (including some that are useful to pastoralism) have become more abundant under grazing. Many species have been unaffected by grazing.

It is difficult to discuss the results in terms of sustainability of current grazing practices because the impacts seen are subtle and do not involve gross loss of perennial species, erosion, or other obvious degradation. The land surface is well covered with perennial plants, while the potential of the land to produce biomass has not been affected.

Of the species contributing to animal production, the suppression of *E. polyphyllus*, and to a lesser extent, of *A. contorta*, is of most concern. However, it is impossible to say that animal productivity has been diminished by this change in pasture composition. Other studies have found that it is difficult to show a relationship between perceived rangeland condition and forage biomass or diet quality (Squires and Low 1987).

There is no doubt that the pasture inside the exclosure seems to have a better balance of coarse perennial grasses (*Eragrostis eriopoda* and *Triodia schinzii*). Nutritious annual grasses (*Enneapogon polyphyllus* and *Aristida contorta*) can contribute up to 40% of total pasture inside the exclosure in a good season. It can generally be concluded that the relatively short 50-year history of livestock grazing at this site has caused some deterioration to the balance of useful pasture plants. However, an equally stable vegetation state has developed under grazing, which, although not as nutritious in good seasons, is inherently more stable, particularly under drought conditions characteristic of the region.

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