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CO-GRAZING CATTLE and CAMELS

A report for the Rural Industries Research and Development Corporation

by
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Foreword

Australia is home to the worlds only large feral camel population. The feral population is descended from camels originally imported as a means of transport for Australia's semi-arid and arid interior. Camels played a key role in the early European settlement of much of inland Australia, however the advent of mechanised transport saw camel usage decline and many were set free. Large areas of land in arid and semi-arid Australia are suitable for grazing camels and the feral population has continually increased. In other countries camels are used for a variety of purposes including transport, meat, milk and fibre, but until recently camel use in Australia was restricted to tourism and recreational purposes.

From the early 1990's onwards there has been considerable effort in Central Australia devoted to developing markets for camels and camel products, particularly camel meat. A shift in focus to live camel exports has seen a recent expansion in the number of camels required for markets. To ensure consistent supply to these markets requires a further move away from harvesting feral camels to producing more "domesticated" camels. In Central Australia this usually means cograzing camels with cattle. Cattle and camels have quite different dietary preferences. Provided they are well managed, both species should be able to be run together without negatively impacting on the environment or each other's production.

This project investigated the animal productivity and vegetation impact of cograzing compared to grazing cattle only. Camel feeding and behavioural observations were also made. The results of these investigations are presented in this report.

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Peter Core
Managing Director
Rural Industries Research and Development Corporation

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Contents

Executive Summary

Background

This project began in July 1997 and fieldwork was completed in May 2001. The project began with the idea that beef producers might achieve unchanged beef production with camel production as a bonus through cograzing the two species. The project was developed against a background of relatively low beef prices and several poor seasons in Central Australia. The overall goal was to investigate the livestock productivity and impact on vegetation of cograzing as opposed to cattle grazing. Differences between grazing cattle only and cograzing cattle and camels were investigated in two paddocks on Waite River station, 250 km by road northeast of Alice Springs. An adjoining paddock that was very conservatively stocked with cattle was used for pasture comparisons. This project focused on biological aspects of cograzing, however it is recognised that continued development of camel markets is essential for successful commercial cograzing to become widely adopted.

The project had four components:
1) Tree and shrub impact monitoring
2) Pasture utilisation monitoring
3) Animal production measurements
4) Camel feeding and behavioural observations

The project used cattle and camels belonging to the cooperating station. In 1996, a camel breeding herd of one bull and 14 cows were introduced to the 8.4 km^2 “Muller paddock”. Camel browsing on trees and shrubs was recorded in 1996 and 1997 prior to this project commencing.

Both Muller paddock and the comparative 20.9 km^2 “DPI paddock” were spelled from cattle grazing over the 1997/98 summer until steers were introduced into both paddocks in March 1998. Steer groups in both paddocks were replaced with the same number of younger steers each year. Camel groups were also changed at the same times as steer groups. The breeding herd of camels was replaced with nine young bulls in March 1999, reducing the camel stocking rate to approximately one per square kilometer. These camels were removed from Muller paddock in April 2000. From August 2000 until May 2001 the stocking regimes were reversed. The DPI paddock was cograzed with steers and 20 young bull camels and Muller paddock ran steers only. The grazing regimes were as follows:

	Muller paddock	DPI paddock
1. Mar 98 – Feb 99	Steers cograzed with breeding camels	Steers only
2. Mar 99 – Apr 00	Steers cograzed with young bull camels	Steers only
3. Aug 00 – May 01	Steers only	Steers cograzed with young bull camels

Seasonal conditions fluctuated markedly during the project:
- the 1997/98 summer and autumn rains were good and consequently so was pasture growth;
- there was no effective rainfall over the 1998/99 summer nor during the 1999 autumn or winter and therefore there was minimal pasture growth; and,
- Both the 1999/2000 and 2000/01 summer and autumn rains were exceptionally high and so was pasture growth.

Such “boom and bust” fluctuations in rainfall and pasture conditions are normal for this and many other arid and semi-arid regions in Australia. The very wet summers and autumns of 1999/2000 and 2000/01 made it necessary to adjust planned project activity. Sourcing livestock for the project became difficult and the self-mustering bayonet traps in the project paddocks were ineffective for extended periods.

Summary of findings

Pasture plants, utilisation and ground cover

Pasture yields fluctuated greatly in response to effective rainfall. Pasture yields were high in late 1997, decreased through 1998 to very low in 1999, and returned to or bettered the 1997 yields in 2000. Seasonal conditions were also the main determinant of pasture composition. Despite large fluctuations in the amount of grass and herbage available, there was no consistent significant difference recorded for any pasture attribute (species mix, quantity, or ground cover) that could be attributed to cograzing camels with cattle. At the stocking rates set for both species, camels did not deprive the cattle of grass or herbage. This was the case in both excellent and poor seasonal conditions.

Tree and shrub impact

Browsing on trees and shrubs cover was also driven by seasonal conditions.

- In 1997 camel browsing resulted in a 15% decrease in tree and shrub canopy cover in Muller paddock whilst outside the paddock, canopy cover increased by over 20%.
- In 1998 good autumn rain and subsequent herbage availability enabled the camels to graze more ground storey species. Canopy cover was stable in the Muller paddock and increased slightly outside the paddock.
- In 1999 canopy cover decreased similarly by almost 10% inside and outside Muller paddock. Outside Muller paddock the decrease in canopy cover was a result of cattle browsing on preferred topfeed species during the dry conditions.
- In 2000 canopy cover increased by approximately 30% in both paddocks due to unusually high rainfall. Extraordinary herbage availability enabled the camels to predominantly graze ground vegetation. Only minor browsing impact on the trees and shrubs in Muller paddock was recorded.
- From August 2000 to May 2001 canopy cover increased everywhere in response to excellent seasonal conditions. The increase was almost 20% in Muller paddock and over 10% in the DPI paddock despite the presence of camels.

Cattle and camel production

The two paddocks in which the project livestock were grazed have somewhat different land types. Variable land types within small distances are quite typical of many of the more productive areas for running cattle in Central Australia. Steer stocking rates in both paddocks were established according to the area of different land types, resulting in Muller paddock always being more heavily stocked with cattle. Muller paddock ran 4.2 steers/km^2 compared to 3.6 steers/km^2 in the DPI paddock. This resulted in 16%, 20% and 13% more kg/km^2 of steer liveweight maintained in Muller paddock in each period.

Steer growth patterns reflected seasonal conditions and were therefore completely different during the first two periods, yet annual weight gain and overall growth rates were very similar. These steer groups had average daily weight gains of between 0.41 and 0.45 kg per day over approximately one year. Annual weight gains were therefore in the range of 150 to 165 kg. Steer growth rates in the eight months from August 2000 to May 2001 were higher. Average daily gains of 0.58 to 0.63 kg resulted in weight gains of 145 to 160 kg over this period.

Average steer weight gains were consistently slightly higher in Muller paddock. Average daily gains of steers were 38 g/day higher between March 1998 and March 1999, 30 g/day higher between March 1999 and April 2000 and 54 g/day higher between August 2000 and May 2001. Although these differences were quite similar, they were not statistically significantly higher during the first two periods, but were significantly higher during the final period. This finding is believed to have been due to the combination of excellent seasonal conditions and different land types, rather than any impact from reversing the grazing regimes. There are minimal areas of sloping country and no externally draining watercourses in Muller paddock whereas the DPI paddock has a relatively high proportion of sloping country that runs into an externally draining watercourse. More water is retained and available for pasture growth in Muller paddock.

Cograzing with camels did not appear to limit steer performance during the two years in Muller paddock, presumably because they were not in competition for feed resources and did not have any other detrimental interactions. Steer growth information cannot be directly compared between years because of different seasonal conditions. However, if steer growth rates were reduced by cograzing, the maximum possible difference was very minor and in the order of 10 grams per day.

In 1998, when the camel breeding herd was in Muller paddock, all camel weights (except calves) fell in autumn when the bull was in rut. Cow and weaner weights recovered three months later. In April 2000 several of the nine young bulls removed from Muller paddock at that time showed signs of rut, and, although there were complicating factors, their weights had fallen by an average of 58 kg since January. Rut is thought to have been stimulated by the presence of one camel cow that was injured and therefore not removed from the paddock with the rest of the breeder herd. In May 2001 none of the young bull camels were showing signs of rut. They gained an average of 109 kg during the eight months, at an average of 260 g/day. It seems necessary to avoid rutting behaviour to optimise camel production. Importantly however, camel rutting behaviour did not affect cattle weight gains.

Cograzing camels with cattle substantially increased the weight of livestock grazed per square kilometre. In the three periods that camels were cograzed with steers, they accounted for 52%, 28% and 26% of the total livestock weight maintained per square kilometer in the cograzed paddocks. Equivalent increases in the cattle stocking rate per square kilometre would be expected to cause their production to suffer under most seasonal conditions. Running young bull camels at stocking rates of approximately one camel per square kilometre with steers resulted in camel weight gains accounting for 10% (after being affected by rutting behaviour) of the total livestock weight produced per square kilometre in 1999/2000 and 16% in 2000/01.

Application in industry

Cograzing is equally, if not more, applicable to the large areas of marginal land for cattle in Central Australia (such as spinifex and mulga country) than to the more productive land types that dominate the paddocks used in this project. The proportional contribution that camels could make to total livestock production would be expected to be higher on land types more marginal for cattle grazing and where there are long distances between water points.

If markets for camels continue to expand and it becomes economically viable to domesticate significant numbers of camels they can be successfully cograzed with cattle. Cograzing may increase variable and capital costs somewhat when compared to grazing cattle only. Extra fence maintenance and upgrades to yard and loading facilities are among the extra costs that might be incurred.

Under careful management, a successful outcome of unchanged cattle production, plus additional camel production can be achieved without negative impact on pasture resources. This project did not demonstrate serious differences in pasture species attributable to cograzing, however it did not run long enough to be able to ascertain long term differences. Despite camels being generally perceived as browsing animals they preferentially graze many broad-leaved pasture plants commonly referred to as herbage or forbs when they are available. They also graze fresh grass growth after the first rains following a dry period, until herbage becomes available. There are therefore some dietary overlaps between cattle and camels for preferred tree, shrub and herbage species and for grass at certain times. Plant species preferred by cattle and camels may become indicators of pasture condition if the practice of cograzing expands.

1. Introduction

The pastoral industries in Australia's semi-arid and arid regions have historically been devoted to wool producing sheep and beef cattle. The past two decades have seen a shift from pastoralism being almost exclusively focused on wool and beef production to include other products from grazing animals in these environments. Examples of efforts to this end have been the importations of Boer goats plus Damara and Dorper breeds of sheep. Camels differ from these species in that they are a potential resource that is adapted to arid environments and already present in Australia. Because they have no significant predators, if left unchecked, the population of camels is likely to continue to increase and cause environmental problems in certain areas.

Large areas of pastoral land in arid and semi-arid Australia are suitable for grazing camels. Land types dominated by Acacia trees and shrubs are particularly well suited to camel grazing. In Central Australia (south of 20°S in the NT) there is approximately 250 000 square kilometres of land on pastoral leases and approximately 50 000 square kilometres of Aboriginal land suitable for pastoral purposes. An estimated 60% of this land is suitable for cograzing cattle and camels. Large areas of suitable lands also exist in the arid and semi-arid areas of Queensland, New South Wales, South Australia and Western Australia.

The industry for meat production from Central Australian camels is a developing one. The industry began in the early 1990's and was heavily reliant on harvesting feral camels from Aboriginal and pastoral land. A 1993 aerial survey estimated there were 60 000 feral camels in the NT and that most of these were on Aboriginal land (Wurst and Saalfeld, 1994). Until recently most beef cattle producers in Central Australia regarded camels as a pest species, principally because bull camels damage fences during the rutting season. The camel industry is now somewhat less reliant on harvesting of feral camels because there are more cattle producers running "domesticated" camels. The camel industry has recently successfully expanded by opening up new live export markets with live shipments to Brunei and Malaysia. If the camel industry develops further, more beef producer attitudes to camels are likely to change from seeing them as a pest to seeing them as a resource. Opening further new markets and/or increasing the size of existing markets will require more camel producers to ensure continuity of supply.

In Central Australia, running camels on land used for pastoral purposes would involve cograzing them with cattle. Cograzing cattle and camels represents one of the few opportunities for agricultural enterprise diversification available to beef producers in Central Australia. If producing camels becomes economically viable on a broad scale, cograzing cattle and camels has potential to improve the profitability of many cattle enterprises in Central Australia without damaging the pasture resource. However, there is a lack of objective information on livestock production and the effects on vegetation of cograzing camels with cattle. A literature search revealed no Australian information on cograzing camels with cattle or any other domesticated species. Published Australian research on grazing more than one domesticated species has concentrated on grazing goats with sheep and sometimes cattle.

Research in Central Australia (Dörges and Heucke, 1995) has shown that camels and cattle have very different dietary preferences. In that study, camels spent up to 97% of their grazing time feeding on shrubs and forbs. Grasses were only of importance after rain before forbs became available. Because camels and cattle have different dietary preferences, cograzing them under careful management should enable greater production per unit area of land without adversely affecting each other's production or damaging the native pasture resource. Anecdotal evidence from pastoralists with camels on their stations suggests that: a) cattle perform better when grazed in paddocks with camels under drought conditions; and b) no difference in cattle performance is noticed under good seasonal conditions. This is thought to be possibly due to a combination of rumen microbe transfer (Miller *et al.* 1996) and that camels enable cattle access to browse that would otherwise be out of their reach by breaking branches. A third possible contributing factor to these observations is an increase in pasture quantity due to opening up of tree canopies in some areas. In East Africa, cattle ranchers use camels at very high densities to reduce bush encroachment and to increase grass production (Evans and Powys, 1979). It is suggested that running camels with cattle in Central Australia might achieve the same result in some situations (Dörges and Heucke, 1989).

The project was carried out on "Waite River", a commercial cattle station in Central Australia. The research site was known not to have been grazed by camels for at least forty years and contained 34 potential topfeed species (including nine *Acacia spp*. and six *Eremophila spp*.). Thus the site provided an ideal opportunity to obtain objective information about the impact of newly introduced camels on topfeed species. Several of these species are classed as woody weeds in certain situations because they have a propensity to take over country and reduce pasture growth.

This research project obtained objective information on the vegetation impact and utilisation, and animal production and management aspects of cograzing, by comparing cograzed paddocks with paddocks grazed by cattle. On the basis of this information some recommendations on cograzing have been developed. These recommendations can be used by industry for land, pasture and grazing animal management decision making if the practice of cograzing expands.

2. Objectives

1. To obtain objective animal production data on cograzed cattle and camels compared to grazed cattle only.

2. To improve knowledge of the impact of camels on native vegetation in Central Australia.

3. To improve knowledge of the impact of camels on woody weed species in Central Australia.

4. To obtain objective data on pasture utilisation by cograzing cattle and camels, compared to grazing cattle only.

5. To demonstrate potential for cograzing species with different dietary preferences to improve productivity and income stability.

3. Methodology

Study Site
The study area was first stocked with cattle around the 1930's and Muller bore (the water point for Muller paddock) was equipped in 1945. Prior to the 1960's, the vegetation structure was more open, often with scattered large mulga (*Acacia aneura*) trees (Bob Purvis *pers. comm*.). The lease over the area was sub-divided in 1972, and the fence between Waite River and Woodgreen Stations was constructed[1].

The project used the existing 8.4 km^2 Muller paddock on Waite River station. An adjoining area of 20.9 km^2 was fenced off and had water supplied to it and was named the DPI paddock. The DPI paddock was larger for practical reasons that suited station management. Land types in Muller and DPI paddocks were mapped using aerial photographs and on-ground survey. These two paddocks and adjoining paddocks on Woodgreen station were used for pasture assessments. Woodgreen was used for the control or benchmark for pastures because of minimal presence of cattle at the outer edge of these paddocks[2]. The location and layout of the study site is shown in Figure 1.

Muller paddock had been opportunistically grazed by cattle for short periods over the prior decade and the DPI paddock area had been part of a larger paddock that had been conservatively grazed by cattle over the prior decade. Both paddocks were spelled from cattle grazing over the 1997/98 summer so that pasture availability in both paddocks was similar. Steers were introduced to both paddocks in March 1998. For two years Muller paddock was cograzed and the DPI paddock ran steers only. In the final year of the project the grazing regimes were reversed. Muller paddock ran steers only, and the DPI paddock was cograzed between August 2000 and May 2001.

A data-logging rain gauge (pluviometer) was installed in the DPI paddock at the beginning of 1998 to measure rainfall volume and intensity, while a storage rain gauge at Muller bore also provided rainfall totals. Pasture assessments were undertaken in April 1999, October 1999, February 2000, and May 2000. Detailed pasture assessments were not undertaken after the grazing regimes in the paddocks were reversed because of the limited amount of time that the reversal ran for.

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[1] This boundary fence separates Muller and DPI paddocks from the paddock on Woodgreen where the pasture control sites were established.

[2] The cattle in the control paddock on Woodgreen rarely grazed to where the sampling sites were located. The only time during the study that there were any signs of cattle in this paddock was during the very dry conditions of October 1999.

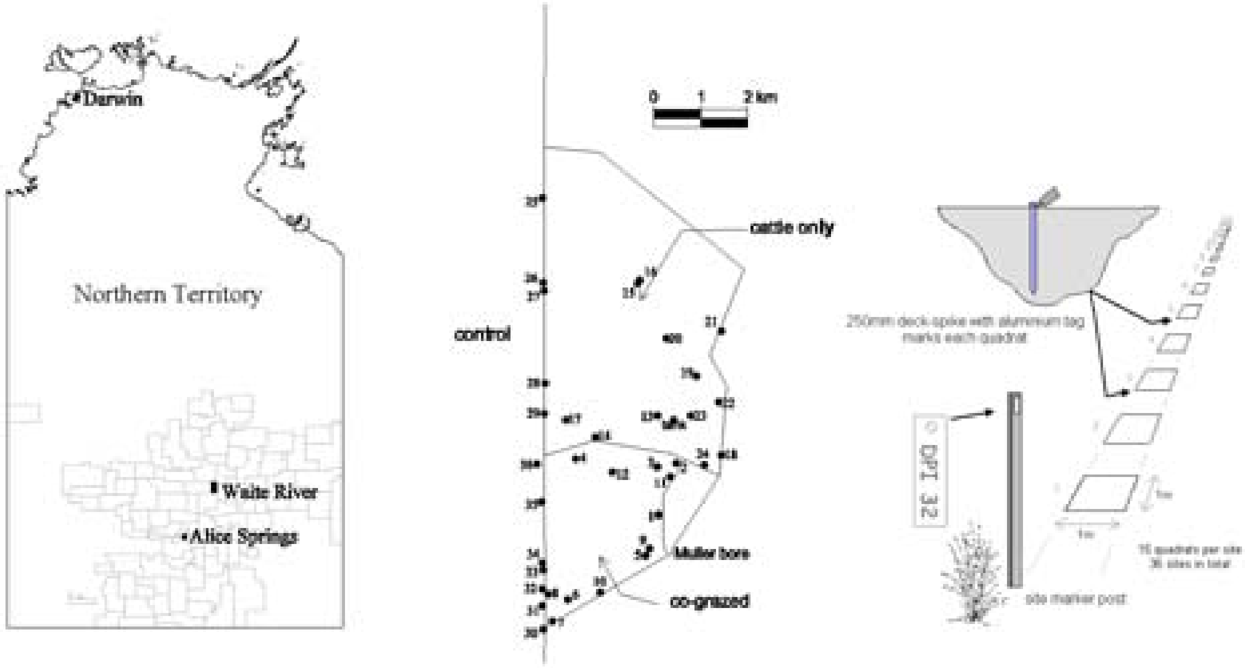


Figure 1. Location of study site and pasture assessment layout

Pasture plants, pasture utilisation and ground cover (Greg O'Reilly)

Pasture assessment sites

Within each paddock 6 sites were selected within each of two land types, being 'run-on' or 'run-off', depending on surface water flows after rainfall. Run-on areas capture more surface water flow and associated nutrients and tend to be the fertile patches in arid landscapes where water and nutrients are in short supply (Tongway and Ludwig 1990). At each site, 15 x 1m^2 quadrats were permanently located along a 30 m transect extending away from a site marker post. This size quadrat has been shown to be the most efficient for Central Australian pasture sampling (Friedel and Shaw 1987). Each quadrat position was marked with a 250 mm deck-spike and numbered aluminium plate tag, pushed into the ground in the bottom left hand corner of the quadrat relative to the site marker post (Figure 1).

Pasture quantity and composition

Within each 1m^2 quadrat (sampling plot), the dry weight of each species was visually estimated in g/m^2 with the assistance of photographic standards of known pasture composition by weight (Wilkie 1997). The visual estimates were adjusted afterwards based on a linear regression equation derived from visually estimating, and then cutting and drying a range of 1m^2 quadrats, positioned adjacent to sampling sites, and which encompassed the range of pasture types and yields encountered during a particular sampling event.

As with almost all pasture data collected in sparsely patterned arid zone vegetation, the adjusted data required combining of quadrats to reduce the number of zero values and to meet the normality requirements for an analysis of variance. Because each quadrat was relocatable, it was possible to combine together data from similar sites within the same land type improving homogeneity of treatment variances. It was found that averaging the data from 15 quadrats gave 12 replications in each treatment suitable for further analysis. Bartlett's test for homogeneity was used to test for normality using Genstat 5[3]. A one-way analysis of variance without blocking ($p<0.05$) was performed on the quantity (yield) of five key pasture attributes (total yield, yield of forbs, yield of perennial grass from run-on land type, yield of annual grass, and yield of *Enneapogon spp.* from run-off land type) after loge(x+1) transforming the data. Where a significant difference was derived ($p<0.05$), the least significant difference (LSD) was used to determine which of the

[3] All pasture data analysis was performed using Genstat 5 (Lawes Agricultural Trust – Rothamsted Experimental station 1998)

treatments differed from each other. The pasture attributes chosen for analysis are those most likely to be affected by the treatments, being important to either cattle production or to the diets of camels.

Relative Frequency

At each $1m^2$ quadrat, the presence or absence of each species was recorded. The relative frequencies for five key pasture attributes (*Salsola kali*, *Sclerolaena spp*., *Sida platycalx*, all forbs, and *Enneapogon spp*.) were arranged in a 2 x 3 contingency table and the maximum-likelihood chi-square test in Genstat 5 was used to determine significant differences. Where a significant difference occurred ($p<0.05$), Fisher's exact test for 2x2 contingency tables was used to determine which of the treatments differed. In cases where expected frequencies for individual cells in the contingency tables were less than 5, the procedure of Zar (1996, p502) was followed. In this procedure the average expected frequency, namely n/(rc), where n is the sample size, and r and c are the number of rows and columns, should be at least 6.0 when testing at the $p < 0.05$ level. The pasture attributes analysed are key species to either the diets of cattle or camels, and it was thought that these species were most likely to be implicated if there was any change to botanical composition as a result of cograzing.

Ground Cover

During the very dry conditions of October 1999, when other pasture measurements involving species identification were not possible in the $1m^2$ quadrats, the percentage of ground covered by standing plants and detached litter was visually estimated. At a randomly selected 37 out of 540 quadrats estimated, photostandard apparatus was used to take a vertical photograph of each quadrat. Afterwards a 64-dot grid was laid over each photographic print and the percentage cover was estimated using the method of Wilkie (1998). Although both methods are still estimates, there is no other easy method for checking the accuracy of visual cover estimates made in the field. The field estimations were regressed against the dot-count method of estimating cover to test the accuracy of visual estimation of cover made in the field. Cover estimation was repeated after good rains in February 2000.

Each cover estimate was classified into a cover class. These classes varied according to the sampling date and land type and were determined from examining the range of estimates recorded. The frequency of sampling plots in each cover class was compared across the three treatments using chi-square analysis of 2x3 contingency tables. Where a significant difference occurred ($p<0.05$), Fishers exact test for 2x2 tables was used to determine which of the treatments differed.

Pasture Utilisation

The percentage of pasture consumed in each of the stocked treatment paddocks was estimated as a percentage of the total yield from the control paddock. The control paddock provided a benchmark for how much pasture was potentially available in the stocked treatment paddocks.

Camel feeding and behavioural observations (Dr Birgit Dörges)

Even though the paddocks were small, radio tracking was essential for locating camels quickly because the paddocks were densely vegetated. One camel was radio collared each year and readily detectable from anywhere in the paddocks. Throughout the project, the location of the camels was noted and their daily activity patterns recorded. The characteristics of the habitat were noted on each of these occasions. The timing of these records coincided with when the tree and shrub vegetation transects were monitored. At selected intervals the activity of the camels was noted and when feeding, the plant species being browsed or grazed was recorded. Any unusual behaviour, such as branch breaking was noted and the species recorded. When possible, quantitative food intake was measured by counting a minimum of 1,000 visible bites from individuals and/or by evaluation of "time budgets" (interval method; Altmann 1974).

Tree and shrub impact monitoring (Dr Jürgen Heucke)

In 1996, twenty vegetation transects were established in Muller paddock to measure the impact of camels on different topfeed species. Ten comparative transects were established outside of Muller paddock. In March 2000 ten additional transects were established in the DPI paddock prior to camels being introduced. Each transect was 200 m long and 4 m wide.

A total of 40 transects in various vegetation units were assessed. The location of the transects is shown below in Figure 2.

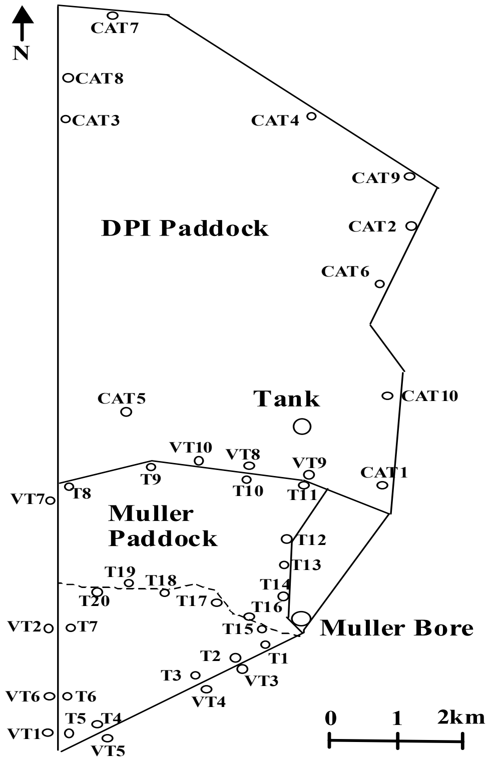


Figure 2. Location of transects; T = Transect 1-20 in Muller paddock; VT = Comparative transects 1-10; CAT = Additional transects 1-10 in DPI paddock

Transects were assessed every three months, unless delayed by wet weather. Every tree and shrub growing on each transect was identified and height measured and any damage or change was recorded. The abundance of shrubs per transect was recorded in seven size classes (<25 cm, <50 cm, <100 cm, <200 cm, <400 cm, <800 cm and >800 cm). Canopy cover was measured on every transect using a rope connected between two posts as a fixed line. Each tree and shrub that covered or was underneath the rope was measured. To ensure that exactly the same transect was measured at each visit, the trees and shrubs were recorded individually. Canopy cover was measured twice yearly in 1996 and 1997 and quarterly from March 1998. Browsing intensity on trees and shrubs intersecting transects was classified in six categories: (0 = not browsed; 1 = nibbled; 2 = slightly browsed, (normal camel browsing); 3 = regularly browsed, some branches broken; 4 = heavily browsed, nearly destroyed, most branches broken; 5 = destroyed, (no regrowth after rain). Changes in canopy cover at sites through time were compared using Paired Student's t-tests in the Excel statistics package. In addition, 30 fixed representative sites were photographed before the camels arrived. These were re-photographed at least twice per year to record changes over time.

Cattle and camel production measurements (Andrew Phillips)

Steer stocking rates for both paddocks were set at what were estimated to be equivalent stocking rates by measuring the areas of individual land types and assigning a stocking rate to each land type. Stocking rates were set by Andrew Phillips and Andrew White (formerly of DPIF) using a combination of local producer recommendations, local knowledge and pasture yields for each different land type. Stocking rates were set such that pasture quantity would not limit cattle production except under poor seasonal conditions. Steers were first introduced to both paddocks in March 1998 and steer groups used in the project were replaced annually. Muller paddock had 35 steers introduced each year, giving a stocking rate of 4.2 steers per square kilometre and the DPI paddock had 76 steers introduced, giving a stocking rate of 3.6 steers per square kilometre.

Steers were six to twelve months old when introduced to the paddocks. Steers were selected so that liveweight was as equal as possible between groups and all steers were individually identified by numbered eartags. The first two steer groups were weighed five times - on entry and at intervals of approximately three months thereafter until they were removed from the paddocks. Steers were supplemented with Uramol® blocks under dry seasonal conditions in the latter part of 1998 and the early part of 1999 as part of normal station management. The final groups of steers were only weighed twice, on entry and on exit eight and a half months later, due to the exceptionally wet seasonal conditions.

After their second weighing in May 1999, half of the steers (17) from the cograzed Muller paddock were swapped with 17 steers of equal liveweight by pairing individuals from the DPI paddock. This gave four groups of steers with growth information: 1) steers grazing with camels all year; 2) steers grazing with, then without camels; 3) steers grazing without, then with camels and 4) steers grazing without camels all year. Weight gains of the steer groups were compared using the Wald test described in Zar (1996). Groups 1 and 4 were principally compared. Groups 2 and 3 were used to determine differences in growth profiles. Steers that were swapped between paddocks had a notch cut in their eartag for ready identification of their treatment group. Time of year effects on steer growth rates were not distinguishable from paddock effects in the analysis but the design allowed determination of differences in growth profiles not due to grazing with camels. Steer weight gains were compared in the final period using Student's t-test assuming equal variances in Microsoft Excel.

In 1996 fourteen camel cows and one bull were introduced to Muller paddock giving a camel stocking rate of approximately two adult camels per square kilometre. This stocking rate was estimated based on the comparative density of trees known to be palatable to camels from a research site at "Newhaven" station northwest of Alice Springs. Several camel calves were born in 1996, 1997 and 1998. The young bull camels that were old enough to wean were weaned in September 1998 and removed from the paddock, whereas the sole female calf was kept in the paddock. In March 1999, the breeding herd of camels was replaced with nine young bull camels. One injured camel cow was not able to be loaded onto the truck for removal, so remained with the young bulls in Muller paddock. This reduced the camel stocking rate in Muller paddock to one camel per square kilometre to address concerns over the prevailing dry conditions. The same stocking rate was used when the DPI paddock was cograzed using 20 young bull camels. Camels were weighed at the same time or close to the same time as the steers.

The grazing regimes were as follows:

	Muller paddock	**DPI paddock**
4. Mar 98 – Feb 99	Steers cograzed with breeding camels	Steers only
5. Mar 99 – Apr 00	Steers cograzed with young bull camels	Steers only
6. Aug 00 – May 01	Steers only	Steers cograzed with young bull camels

Total livestock productivity of Muller and DPI paddocks was measured in terms of kilograms liveweight maintained and produced per square kilometre. Initial steer and camel liveweights were totaled and this total divided by the paddock area to calculate the livestock weight maintained per square kilometre. Final steer and camel liveweights were subject to the same procedure. The difference between the final and initial liveweight per square kilometre was the liveweight produced per square kilometre.

4. Results

Camel feeding and behavioural observations

Feeding behaviour
The food spectrum of camels is related to the amount of rainfall. Under dry conditions camels generally feed on trees and shrubs, however after substantial rainfall they alter their browsing habits and feed predominantly on ground storey vegetation. Monthly rainfall totals from 1996 to April 2001 at Muller Bore and a local long-term average are shown below in Table 1.

Table 1. Monthly rainfall at Muller bore from 1996 to May 2001 and the long-term average on neighbouring Alcoota station.

	Alcoota	**Muller Bore**					
	1951-93	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
Jan	59	0	187.5	30.5	53.5	16	150.5
Feb	48	7.5	137.5	64	15	256	48
Mar	30	46	0	0	14	6	73
Apr	19	14	0	119	0	143.5	0.5
May	23	0	25.5	0	0	15	0
Jun	11	0	0	14	32	0	n/a
Jul	16	12.5	1.5	0	0	0	n/a
Aug	8	7	0	8.5	0	0	n/a
Sep	8	0	3	9.5	20.5	0	n/a
Oct	20	28.5	16.5	28.5	67.5	12.5	n/a
Nov	27	0	13.7	10	73.5	103	n/a
Dec	32	32	65	18.5	85	196	n/a
Total	**301**	**147.5**	**450.2**	**302.5**	**361**	**748**	**272**

Quantitative food analyses:
The food spectrum of camels is extremely variable and was related to the amount and timing of rainfall. Food intakes from four observation periods demonstrate this flexibility (November 1996, and December 1997, 1998 and 1999) and are shown in Figure 3. In December 2000 a quantitative food intake observation was not possible. Heavy rainfalls made a close approach to the camels impossible as the country was too wet. It is expected though, that the camels fed predominantly on the ground storey vegetation under these conditions. Results of the quantitative food intake observations over the whole period of investigations split between ground storey and topfeed species are shown in Appendix 3. Detailed results of numbers of browsed individuals in each observation period are shown in Appendices 4, 5 and 6.

In November 1996 the camels ate predominantly topfeed with *Acacia estrophiolata* (Ironwood), *Atalaya hemiglauca* (Whitewood) and *Grevillea striata* (Beefwood) being the main dietary components. Forbs from the chenopodiaceae family (*Atriplex, Enchylaena* and *Salsola*) were mostly eaten from the ground vegetation.

In December 1997 only 27% of the observed camels diet was topfeed with *Acacia estrophiolata*, *Acacia victoriae* (Acacia Bush), *Atalaya hemiglauca* and *Corymbia aparrerinja* (Ghostgum) being the main components. Grasses were predominantly consumed from the ground storey vegetation. The grasses were lush and green due to recent rain, whereas the forbs were still very small.

In December 1998 the camels diet consisted overwhelmingly of topfeed with *Acacia aneura* (Mulga), *Acacia estrophiolata* and *Acacia georginae* (Georgina Gidgee) being the main components. The only forb available in abundance from the ground storey was *Abutilon otocarpum* (Desert Chinese Lantern). This species as well as some dry grasses were eaten.

In December 1999 the camels fed exclusively from the ground storey vegetation. Forb species from the genus *Boerhavia* and *Tribulus* dominated the quantitative food analysis. These findings reflect the typical feeding pattern of camels. They use the freshest or most preferred species almost exclusively when they are available.

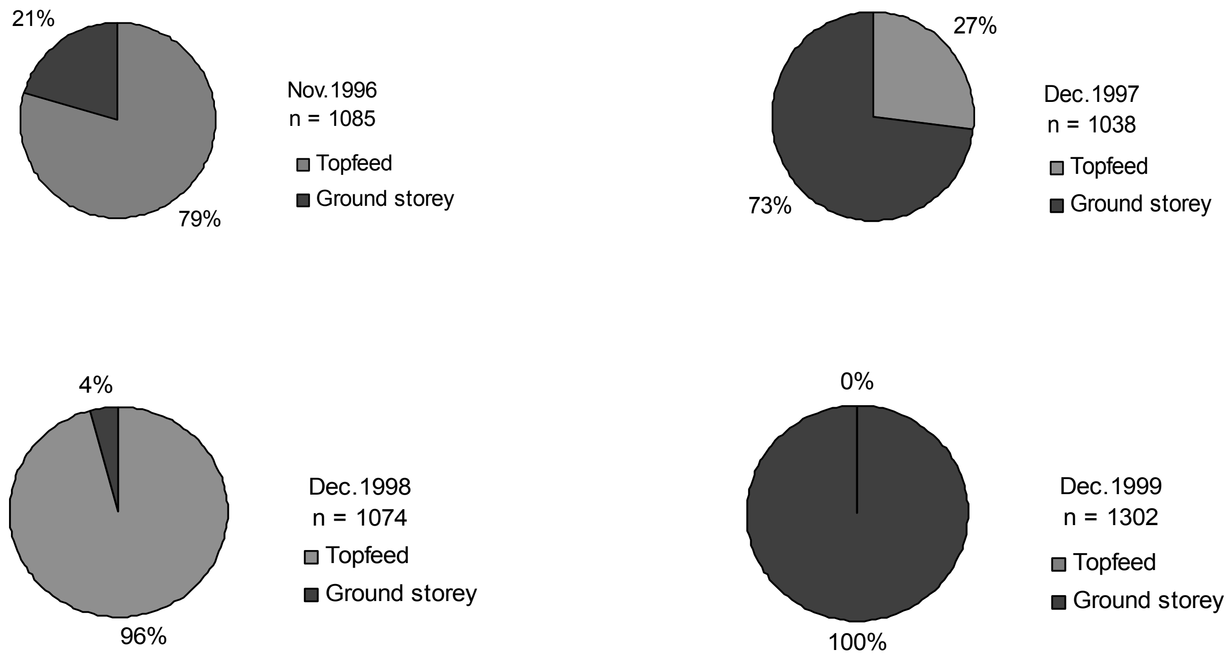


Figure 3. Observed food intake in early summer in 1996, 1997, 1998 and 1999

When the breeding group of 15 camels was introduced into Muller paddock in July 1996 they were conservative in their choice of food plants during the first few weeks. They predominantly fed on those plant species that they knew from their previous home on Newhaven station northwest of Alice Springs. They browsed *Acacia victoriae*, *Acacia ligulata* (Dune Wattle), *Atalaya hemiglauca*, *Rhagodia eremaea* (Tall Saltbush), *Ventilago viminalis* (Supplejack) and other previously well known species. Slowly they adapted to the new species, for example *Acacia estrophiolata* became one of their main food plants in Muller paddock. It took almost a year until the camels browsed *Acacia georginae* regularly. The same conservative feeding pattern was observed with the 20 young bulls, when they were introduced into the DPI paddock in August 2000. Like the first group of camels they slowly adapted to new species. This was particularly observed with browsing on *Santalum lanceolatum* (Plumbush).

When food resources became sparse camels pulled down branches of trees and shrubs and broke them off. Branches up to 10 cm in diameter were broken off by camels. In the dry period of 1999 the cattle in Muller paddock benefited from this behaviour. The cograzed cattle were regularly observed to feed from freshly broken *Acacia aneura* branches.

According to the time spent in the paddocks some characteristic feeding patterns occurred. Following the above described conservative feeding pattern after the introduction into a new area, the camels used first those plant species they knew and preferred. In 1996 they predominantly browsed on *Atalaya hemiglauca, Acacia victoriae* and *Ventilago viminalis*. From the ground storey vegetation *Sclerolaena bicornis* (Goathead Burr) and *Sclerolaena cornishiana* (Cartwheel Burr) were mostly eaten. In 1997 heavy rains fell in January/February, accordingly the camels grazed the ground storey vegetation, especially forbs from the genus *Boerhavia* and *Tribulus*. Dry autumn and winter months followed in 1997 and in response to the drier conditions the camels fed predominantly on trees and shrubs. *Acacia estrophiolata, Acacia georginae* and *Acacia kempeana* (Whitchetty Bush) were the most frequently browsed shrub species at that time. In 1998 the camels had access to, and fed mostly on abundant herbage growth. The observation period of December 1998 to September 1999 was characterised by extremely dry conditions; accordingly the camels predominantly browsed topfeed. During the summer of 1998/99 heavy browsing was observed on *Acacia georginae, Acacia aneura, Grevillea striata, Hakea divaricata* (Fork-leaved Corkwood), *Hakea suberea* (Long-leaf Corkwood), *Acacia estrophiolata*, *Corymbia aparrerinja* and *Corymbia opaca* (Bloodwood). Unusual browsing behaviour occurred in June 1999, when severe browsing on *Acacia georginae* was observed, with some individual trees being completely defoliated by the camels. The observation period from December 1999 to September 2000 was characterised by camel's ability to always feed on the freshest food plants available. The main food components were forbs and occasionally some grasses. *Salsola kali*. (Buckbush) and various *Sclerolaena* species, which flourished after the rains, were predominantly eaten. Only a little browsing on new shoots of *Atalaya hemiglauca*, *Acacia aneura*, some *Corymbia* species and on flowering *Acacia kempeana* took place. In the first half of 2000 the camels in Muller paddock fed mostly on ground storey vegetation .

During the observation period in September 2000 the food spectrum of the 20 young bulls in the DPI paddock consisted of leaves and flowers from the following shrubs and trees: *Acacia aneura, Acacia kempeana, Acacia ligulata, Acacia victoriae, Atalaya hemiglauca, Amyema maidenii* (Pale-leaf Mistletoe), *Canthium latifolium* (Native Currant), *Codonocarpus continiifolius* (Desert Poplar), *Eremophila longifolia* (Emu Bush), *Grevillea striata, Glycine falcata* (no common name), *Jasminum didymum* (Native Jasmine), *Rhagodia eremaea, Santalum lanceolatum* and *Ventilago viminalis*. From the ground storey vegetation they predominantly ate: *Calandrinia balonensis* (Broad-leaf Parakeelia), *Calotis latiuscula* (Leafy Burr-daisy), *Enchylaena tomentosa* (Ruby Saltbush), *Lepidium phlebopetalum* (Veined Peppercress), *Portulaca oleracea* (Munyeroo), *Salsola kali, Stenopetalum nutans* (Nodding Thread-petal), *Scaevola parvifolia* (Fan-flower) and *Trichodesma zeylanicum* (Camel Bush).

In April 2001 due to the good seasonal conditions the camels fed mostly on ground storey vegetation. *Pterocaulon sphacelatum* (Apple Bush or Mint Weed) was particularly heavily browsed. Only minor tree and shrub browsing was observed on *Acacia victoriae, Atalaya hemiglauca, Rhagodia eremaea* and *Ventilago viminalis*. Unexpectedly heavy browsing was monitored on *Santalum lanceolatum*. The camels returned to both stands of this species in the DPI paddock regularly to feed on freshly grown leaves, leaving the bushes almost completely defoliated

Range Utilisation and Habitat Use

The camels at Waite River lived in relatively small paddocks. Restricted by fences, they used the entire area. Seasonal patterns were hard to define, but they used those habitats with high abundance of preferred food plants at certain times. During dry periods, especially in June and September 1999, the camels were mostly found in dense vegetation units and in the Gidgee. After periods of rain they mostly lived in open habitats where there was plenty of fresh forbs. During the hot summer months they spent their extended daily resting periods in areas with big trees like *Acacia georginae* or *Ventilago viminalis* that provided good shade.

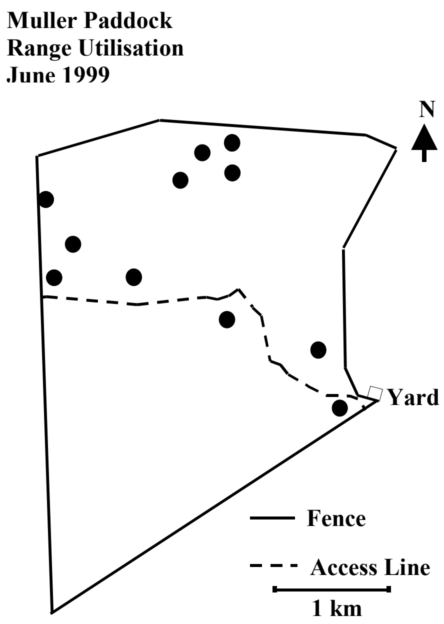


Figure 4. Example of range utilisation in Muller paddock.

In June 1999 the camels continually wandered from the gidgee stands at the northern fence into the thickest shrubs along the access line and the western fence.

Range utilisation and habitat use by the bull group in the DPI paddock followed similar patterns to the breeding group in 1996. After the young bulls were released from the yard they explored the new area. They followed most of the fence line and later remained in the northern and western part of the paddock. In the observation period during September 2000 they were mostly found in open to semi-open habitat types. All records of range utilisation monitored during the project are shown in Appendix 2.

Daily activity patterns
The activity pattern of the camels was subject to strong seasonal fluctuations. A general pattern can nevertheless be described. In summer, activity generally began before sunrise between 5 and 6 am and depending on the air temperature continued until around midday. The camels then rested for differing lengths of time. They had extended rest periods during the hottest time of the day in the shade of big trees for up to six hours. After resting, their activity continued until early or late in the evening and they regularly fed at night in summer.

During the winter months the pattern changed. Activity only began after sunrise and continued throughout the day, interrupted only by short resting phases in the sun. The camels became inactive relatively early in the evening and in contrast to the summer months they rested almost exclusively at night.

Reproduction
Data on reproduction were recorded from 1996 until March 1999, when the breeding herd was removed form Muller paddock. Between June 1996 and September 1998 a total of 19 camel calves were born. All survived, except for one calf that was born just after they arrived. Reproductive information is shown below in Table 2.

Table 2: Camel reproduction rate data

Year	No. of cows	Calves born	No. male calves	No. female calves	Calving %	Calf survival%
1996	14	9	8	1	64%	89%
1997	14	4	3	1	29%	100%
1998	14	6	2	4	43%	100%

After the breeding herd was removed one cow with an injured leg remained in Muller paddock together with the nine bull camels. She had a calf in 1999 that did not survive, most likely due to infanticide.

Social Organisation
While the breeding herd was run in Muller paddock, distinct formation of groups was observed. In the beginning, the breeding group of one bull and 14 cows remained stable. Before parturition the cows segregated and gave birth in seclusion. Later, mother and calf joined up with other new mothers, forming new groups that were subsequently stable until the young were weaned. The 1996 born male weaners wandered between groups, whereas the single female weaner stayed with the wet cows, an adaptive behaviour that allows young females to learn from experienced mothers.

The male weaners were removed in September 1998 to control the camel stocking rate. Before their removal the adult bull grew considerably more aggressive towards them. During the 1997 rutting season the adult bull herded the females with one year old calves. At the beginning of the 1998 rutting season he swapped to the other female group, which by then had one year old calves.

Compared to the relative stable cow groups the young bulls had only loose associations. Groups were often formed on a daily basis. Amongst the young males within a group, playing and play-fighting occurred frequently.

In August 2000 a total of 20 young bulls were put in the DPI paddock. Within a few days of living together two bulls showed increasingly dominant behaviour. Aggressiveness between these two individuals led to the formation of two groups. As bachelor groups are generally not stable, there was an exchange of members between these groups, except for the two now dominant males.

Interaction between cattle and camels
Aggressive interactions between camels and cattle were not recorded, even when both species were kept together in the yard. Camels and cattle were regularly observed drinking next to each other, or feeding from the same shrubs provided for camels whilst in the yard. In the dry period of 1999 a frequent behaviour pattern was observed. Camels are known to break branches of trees and bigger shrubs, to reach higher, more palatable leaves. After camels have fed from those broken branches, there was still a lot of leaf material left. The cograzed cattle thus had access to these higher leaves that would not be available without the camels. In many instances, cattle were observed to feed from the freshly broken branches. This occurred most with mulga (*Acacia aneura*) branches.

Tree and shrub impact monitoring

Tree and shrub canopy cover was measured before the camels were introduced in 1996. Canopy cover was measured to assess browsing impact on transects inside and outside the cograzed areas. These changes are shown below in Table 3.

Table 3. Percentage changes in canopy cover between years on transects inside Muller paddock and comparative transects outside Muller paddock and in the DPI paddock. Changes that were statistically significantly different are indicated.

Year	**1996-1997**	**1997-1998**	**1998-1999**	**1999-2000**	**2000-2001**
Muller paddock	-15.5% p=0.001	±0% n.s.	-8.8% p=0.01	+30% p=0.01	+19.4% p=0.001
Outside Muller paddock	+22.4% p=0.01	+4.7% n.s.	-9.5% n.s.	+33% p=0.01	+9.1% p=0.01
DPI paddock					+11.8% p=0.01

Between 1996 and 1997 there was an obvious decrease in canopy cover in Muller paddock, whereas on comparative transects outside Muller paddock, canopy cover increased. 1996 was the driest year, with a total of 147.5 mm of rainfall. In 1997 heavy rain fell in January and February. This was followed by dry autumn and winter months. In September 1997, after the dry winter, the biggest camel browsing impact was recorded.

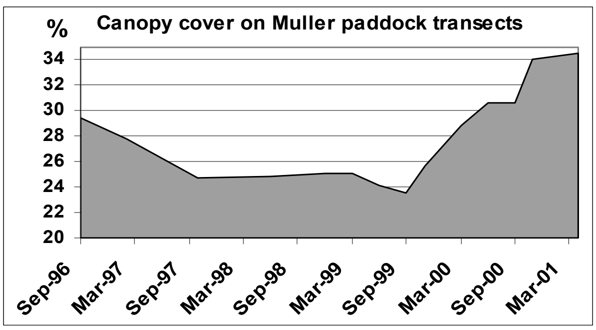
By the end of 1998 the camel density had increased to 4.1 camels per km² (n = 34) through births. However, substantial rainfall occurred during the 1997/98 summer and the camels mostly grazed from the ground, resulting in only minor browsing impact on trees and shrubs. Because the camels browsed less during this good season the canopy cover in Muller paddock remained stable despite of the relatively high camel stocking rate. On the comparative vegetation transects there was only a minor increase in the canopy cover recorded. In 1998, when it became drier they utilised more and more trees and shrubs.

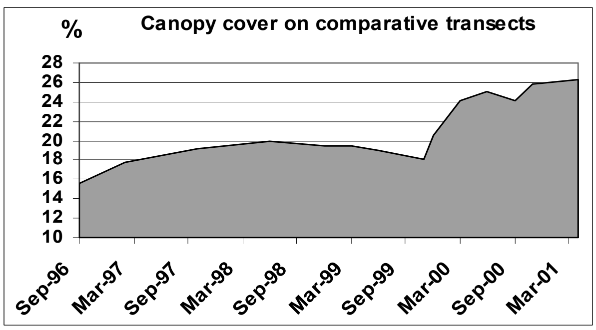
The period from October 1998 to August 1999 was characterised by dry conditions with a total of 162.5 mm of rain. Accordingly, for most of 1999 the camels predominantly browsed trees and shrubs. However, browsing impact in Muller paddock was less than in September 1997. This result was due to the reduced number of camels. The seven sub-adult bulls, born in 1996 were taken out in December 1998, reducing the density to 3.2 camels per km² up to March 1999. In March 1999 the breeding group was taken out and nine bulls and one cow remained in Muller paddock. From March 1999 to April 2000 camel density in Muller paddock was stable at 1.2 camels per km².

Dry conditions led to significant cattle browsing between May and September 1999, the first cattle browsing impact recorded both outside and inside Muller paddock. Outside Muller paddock heavy cattle browsing was recorded on *Atalaya hemiglauca, Ventilago viminalis, Eremophila longifolia, Acacia aneura* and *Acacia kempeana*. Inside Muller paddock cattle browsing was recorded predominantly on *Acacia kempeana*. The topfeed species *Atalaya hemiglauca, Ventilago viminalis* and *Eremophila longifolia* that are preferred by both cattle and camels were browsed beyond the reach of the cattle inside Muller paddock.

In 2000, the camels in Muller paddock fed mostly on ground storey vegetation. The good season combined with a lower density of camels, resulted in an increase of canopy cover. The first recorded increase since the introduction of the camels. Canopy cover increased slightly more outside Muller paddock.

In April 2000 the camels were removed from Muller paddock. A new group of camels was introduced into DPI paddock in August 2000. Heavy rain fell during summer 2000/01 and the crown cover of all transects increased, including the now cograzed DPI paddock. The development of crown cover is shown in Figure 5.





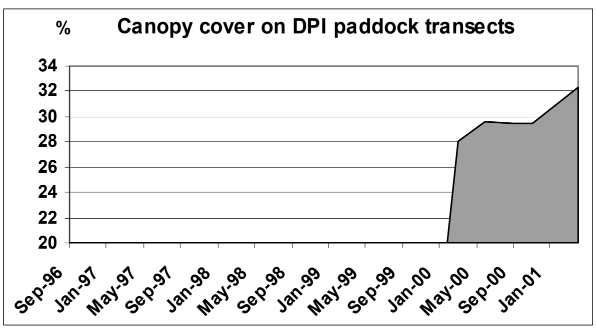
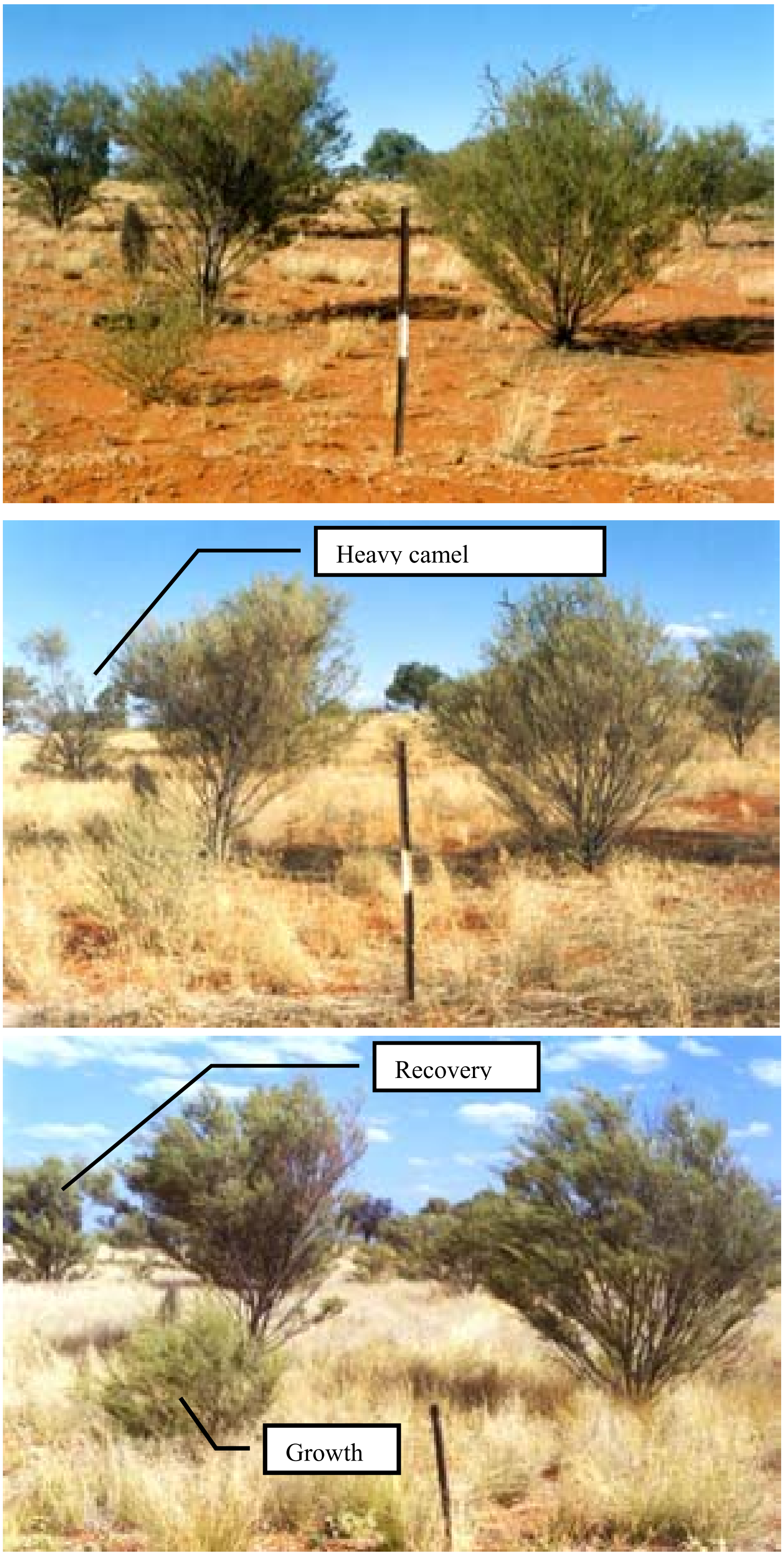


Figure 5. Development of canopy cover in Muller paddock, on comparative transects outside Muller paddock and in the DPI paddock.



June 1996
Canopy cover before camels were introduced in the middle of a poor season.

September 1997
Canopy cover decreased after camel browsing. Dry seasonal conditions followed good summer rains.

September 2000
Canopy cover increased under excellent seasonal conditions six months after camels were removed.

Figure 6. An example of changes in mulga canopy cover in Muller paddock.

Detailed results of browsing impact on tree and shrub species.
Thirty-four tree and shrub species were recorded during the project. The camels used 25 of these species regularly, but browsing activity was neither observed nor recorded on 9 species. These species are listed below in Table 4.

Table 4. Tree and Shrub species recorded in the paddocks on Waite River using nomenclature according to Albrecht *et. al*., (1997). Palatability of species utilised are categorised: 1 - highly preferred; 2 – moderately preferred and 3 – occasionally utilised.

Species use observed and monitored	**Palatability**	Species use not recorded
Acacia farnesiana	1	*Eremophila duttonii*
Acacia victoriae	1	*Eremophila freelingii*
Atalaya hemiglauca	1	*Eremophila gilesii*
Capparis mitchellii	1	*Eremophila latrobei*
Eremophila longifolia	1	*Eremophila sturtii*
Jasminum didymum ssp. Lineare	1	*Senna artemisioides ssp. filifolia*
Rhagodia eremaea	1	*Senna artemisioides ssp. hybrid*
Rhagodia spinescens	1	*Senna artemisioides ssp. quadrifolia*
Santalum lanceolatum	1	*Senna pleurocarpa*
Ventilago viminalis	1	
Acacia aneura	2	
Acacia estrophiolata	2	
Acacia georginae	2	
Acacia kempeana	2	
Acacia ligulata	2	
Acacia murrayana	2	
Acacia tetragonophylla	2	
Canthium latifolium	2	
Codonocarpus continifolius	2	
Stylobasium spathulatum	2	
Corymbia aparrerinja (Eucalyptus papuana)	3	
Corymbia opaca (Eucalyptus opaca)	3	
Grevillea striata	2	
Hakea divaricata	3	
Hakea suberea	3	

Species on the transects affected by camel browsing
Acacia aneura (Mulga)
Two forms of mulga occur at Waite River, the narrow leaf type (*Acacia aneura var. conifera*) and the broad leaf type (*Acacia aneura var. latifolia*). The broad leaf type mulga was clearly preferred by camels. Mulga was browsed at all times of the year. Browsing the intensity varied depending on the availability of ground storey vegetation and was higher when they had flowers or fruit. Severe damage on mulga was recorded on the transects in the dry periods of September 1997, June 1999 and September 1999. Maximum browsing damage was recorded in individuals between two and four metres high. The number of individual mulga plants remained relatively stable on the transects, whereas it increased on the comparative transects. Browsing pressure was high at times, but mulga is common and relatively resilient to camel's browsing. Mulga belongs to the semi-preferred species at Waite River. Changes in mulga canopy cover are shown in Figure 6.

Acacia estrophiolata (Ironwood)
Ironwood was the most abundant species on the transects in Muller paddock. It's quantitative use was first observed after a familiarisation period, as the species was "new" for the camels. Ironwood was used all year round, especially in dry periods. Camels prefer the adult, "weeping" ironwood between two and eight metres high. In the driest times however, even smaller juvenile ironwoods were regularly heavily browsed. The number of individual ironwood trees declined on all transects and comparative transects. The reduction in ironwood population was not considered to be due to camel's browsing but for other reasons.

Acacia farnesiana (Prickly Mimosa, Needlewood)
Prickly Mimosa belongs to the preferred food plants of the camels, all size classes are used. Only one bush was available on a transect in Muller paddock, but disappeared within the first six months of the assessments. Other individuals in Muller paddock were heavily browsed, and by the dry times of 1999 had been completely defoliated. In spite of the good seasonal conditions and removal of the camels from Muller paddock in April 2000, regrowth of these *Acacia farnesiana* plants did not occur until April 2001.

Acacia georginae (Georgina Gidgee)
Georgina gidgee was another "new" species for the camels. It took more than a year until the first browsing of this species was recorded. From September 1997 onwards, Gidgee was browsed regularly. Browsing intensity varied according to the availability of ground storey vegetation and was highest in the very dry period of 1999. In June 1999 some individual trees were completely defoliated by the camels. Ninety percent of the recorded browsing on Georgina Gidgee was in the sizes between two and eight metres high. The number of individuals increased slightly on the transects in Muller paddock, whereas the number of individuals increased more on the comparative transects.

Acacia kempeana (Whitchetty Bush)
Witchetty Bush belongs to the semi-preferred food species of the camels. They use it especially when in fruit. Very heavy browsing was recorded on some plants in September 1998, some individuals were nearly destroyed whereas others were not even touched. Preferred sizes are between two and four metres high. The number of individuals slightly increased in Muller paddock and increased more outside on the comparative transects. Whitchetty Bush was the main topfeed for the cattle in Muller paddock during the dry period of 1999.

Acacia ligulata (Dune Wattle)
Dune Wattle was regularly used by the camels. Almost all sizes between 0.5 and four metres were browsed. A disease killed many fully grown bushes which caused a severe decrease on this species. After the heavy rainfalls during the summer 2000/1 some new Dune Wattles germinated from seed.

Acacia murrayana (Colony Wattle)
Colony Wattle is a preferred food plant and is browsed in sizes from 0.5 to four metres high. There is only one small stand in Muller Paddock. It was severely browsed during all drier periods but always recovered after rainfall. Especially after the wet summer 2000/01 when the numbers of individuals doubled as this species can grow from root suckers.

Acacia victoriae (Acacia Bush, Prickly Wattle)
Acacia bush is the main food plant of camels in Australia. Despite not being very abundant in Muller paddock, an impact was seen three days after the release of the camels into this area. Although this acacia tolerates very high browsing pressure and survives after being trimmed heavily, about 70% of this species vanished after the first year. The remaining individuals struggled with a few remaining leaves and five or six flowers during the flowering season. After reducing the camel stocking rate in March 1999 some recovery of this species was recorded. After the rain in summer 2000/01 many new seedlings germinated regaining the numbers on the vegetation transects in Muller paddock before the introduction of camels (1996: n = 92; 2001: n =91). On the comparative transects which were unbrowsed an unexplainable decrease of 13% occurred.

Atalaya hemiglauca (Whitewood)
Whitewood is another favourite food plant of camels and is browsed in all sizes between 0.25 and 8 metre high. Those between one and four metres high were stripped heavily and some eventually died. Although badly damaged, most of this plant species recovered to a degree or developed new shoots from the root system. After the camels were removed from Muller paddock and the good seasons there was an increase in the number of individuals (11%) on the transects but the increase on the comparative transects was much higher (57%).

Corymbia aparrerinja (Ghost Gum) and *Corymbia opaca* (Bloodwood)
Both eucalyptus species were eaten quite regularly especially during the summer, but no real impact was recorded. The number of bloodwood individuals on the transects in the Muller paddock doubled as a result of the good seasons.

Grevillea striata (Beefwood)
Beefwood was mainly eaten during the flowering season. The camels mostly fed on the sweet flowers but also ate the leaves. A browsing effect on beefwood was quite obvious, but except for occasional broken branches, no real damage was recorded.

Hakea divaricata (Fork-leaved Corkwood) and *Hakea suberea* (Long-leaved Corkwood)
The camels only fed on the flowers of these two species. No damage was recorded.

Jasminum didymum (Native Jasmine)
Native Jasmine was regularly browsed all year long and was often trimmed severely but never destroyed. All sizes between 0.25 and 2 metres high are used. This species belongs to the preferred food plants of camels.

Rhagodia eremaea (Tall Saltbush) and *Rhagodia spinescens* (Spiny Saltbush)
Both of these shrubs are highly favoured food plants for camels and were browsed all year round. All sizes between 0.25 and 4 metres were used. As *Rhagodia spp.* species mostly grow under trees or other bigger bushes, the camels were obviously seeking them out. The tiny branches were sometimes pulled out of the thickest shrubs and camels had a high impact on both species. Many individuals which were not well hidden eventually vanished. After reducing the density of camels in March 1999 and the good seasons a substantial increase in the number of individuals was recorded.

Ventilago viminalis (Supplejack)
Supplejack is a very highly preferred plant species that is always browsed by camels. Almost all sizes between 0.5 and 8 metres high were used. Big trees showed a distinctive browsing horizon at about 3m high after a short time. Smaller individuals were under high pressure and some even died. After reducing the camel numbers, then removing the camels from Muller paddock this species recovered very well in the good seasons either by developing new branches or germinating from seeds. The numbers of individuals on transects almost doubled in the Muller Paddock but were unexpectedly stable on the comparative transects.

Additional species that did not occur on transects in Muller paddock but were browsed by camels
Capparis mitchellii (Wild Orange)
Wild Orange occurred on one transect in the DPI paddock and two single individuals were found in Muller paddock. They were regularly browsed and severely trimmed but not destroyed. After the camels were removed the *Capparis* did not recover well where it had been eaten off. This species is one of camels favorite food plants and will always be eaten, even in the best seasons.

Canthium latifolium (Native Currant)
Native Currant occurred on one transect only in the DPI paddock and a single individual was found in Muller paddock. The plant in Muller paddock showed traces of browsing while the other one was never fed on. This was thought to be due to the abundance of more preferred species.

Eremophila longifolia (Emu Bush)
Emu bush was the only species of the six available from the *Eremophila* genus that was browsed by camels. There were only a few individuals in Muller paddock and none on the transects at the start of the project in 1996. The camels fed regularly on them and numbers were decreasing. After the camels were removed this species recovered very well during the good seasons that followed.

Santalum lanceolatum (Plumbush)
Plumbush occured only in the DPI paddock. This was obviously the most preferred species of the trees and shrubs available to camels at Waite River. Even after the exceptionally good season in summer 2000/01 when the camels fed predominantly on the ground vegetation, plumbush was severely browsed. The camels regularly checked for regrown leaves and fed on them immediately.

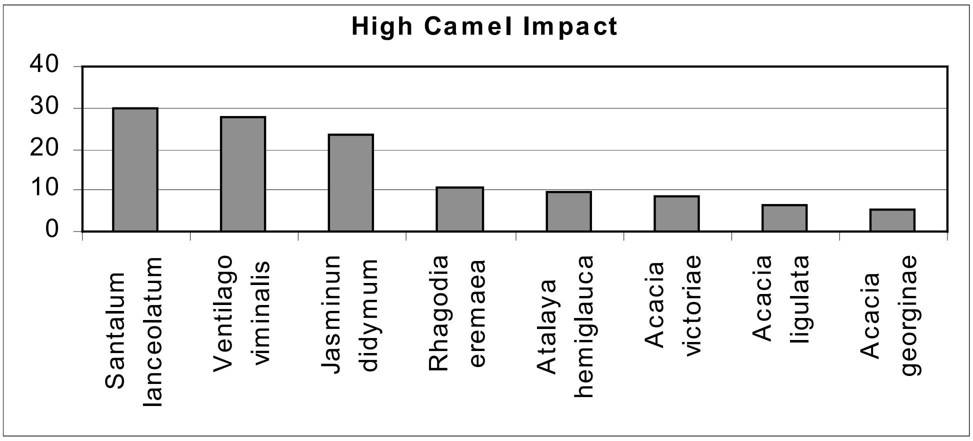
Stylobasium spathulatum (no common name)
This species occured only in the DPI paddock. This is often a common food plant elsewhere, but was hardly touched due to the good season and the abundance of more preferred species.

Of the nine species that were not recorded as browsed during the study period, five species are known to be camel food plants in other areas in Central Australia. These species are: *Eremophila duttonii, Eremophila freelingii, Eremophila latrobei, Senna artemisioides ssp. filifolia* and *Senna pleurocarpa*.

Evaluations of browsing intensity and browsed individuals per transect led to a browsing pressure index that was calculated using the following formula:

Browsing Pressure Index = I x N/A
(I = browsing intensity; N = browsed individuals; A = abundance of browsed species on the transect)

A summary of the browsing pressure indices for those tree and shrub species occurring on all cograzed transects, are shown in Figure 7.



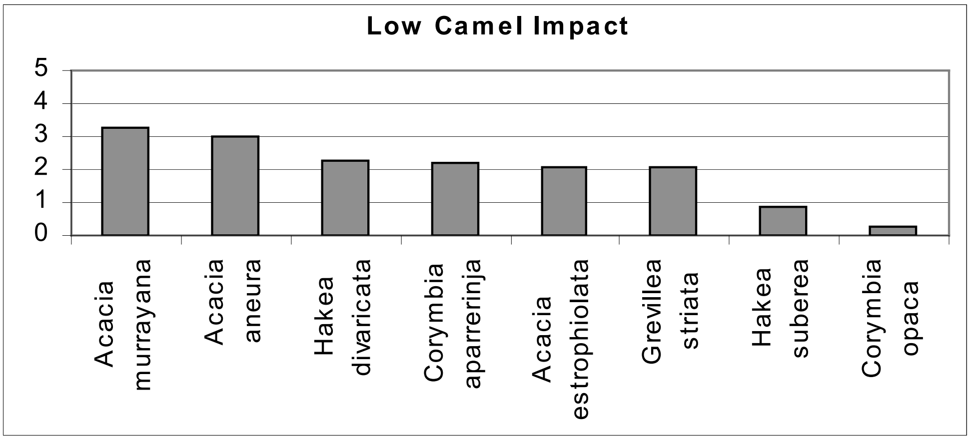


Figure 7. Calculated browsing pressure indices for tree and shrub species occurring on all cograzed transects at Waite River.

Pasture plants, pasture utilisation and ground cover

Seasonal conditions

The first pasture assessment was conducted in April 1999, 14 months after steers were introduced to the project paddocks. In that time seasonal conditions had gradually deteriorated after a promising break to drought conditions in 1997. Some winter (forb growing) rain fell in April 1998, but summer (grass growing) rains were below average the following summer as shown in Figure 8. By the time of the first pasture assessment, there had been little growth of pasture grasses, with just the residues of 1997 grasses remaining in the control paddock on Woodgreen.

Conditions had deteriorated even further by the time of the second pasture assessment six months later in October 1999. By this time it was difficult to identify grass species residues, and total available pasture in the cograzed paddock fell as low as 32 kg/ha. However at this time there were also considerable numbers of grass and forb seedlings which could not be accurately identified, and as it turned out, this heralded the start of an unprecedented run of good summer rainfall months.

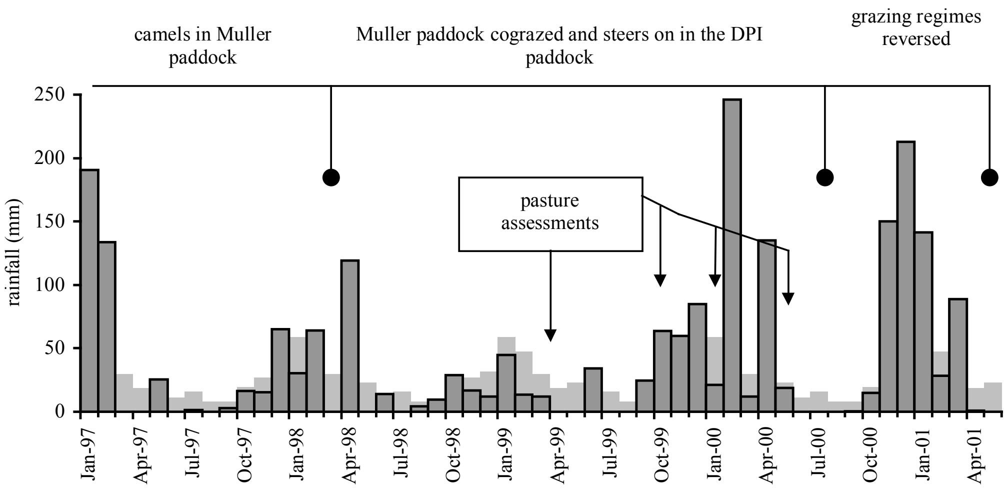


Figure 8. Time-line of the cograzing project showing monthly rainfall totals against long term averages (light grey) as well as the timing of key treatment changes and timing of pasture assessments.

Above average rainfall was recorded in October, November, and December 1999, and after a break in January 2000, excellent grass growing rains fell in both February and April 2000. Pasture assessments in February and May 2000 (24 and 27 months after steers had been introduced to the paddocks) were undertaken in excellent seasonal conditions experienced only every 20 to 30 years in Central Australia.

Excellent seasonal conditions prevailed when the project paddocks had their treatments swapped in August 2000, for the last eight months of the project. Once again very high summer rainfall months were recorded in November and December 2000, as well as in January and March 2001.

Pasture utilisation

Pasture utilisation results in Figure 9 show that pasture utilisation varied markedly throughout the project. The very dry conditions experienced during 1999 resulted in up to 80% of total pasture being consumed in the Muller paddock, based on what was available in the control paddock. This level of utilisation was not sustainable and it was fortunate that good rains began soon after this pasture assessment. By the time of the next pasture assessment, four months later, total pasture utilisation was back to 10-20% in the stocked treatment paddocks, clearly demonstrating the 'boom and bust' cycle of Central Australian pasture production.

At all pasture assessments, *Enneapogon spp*. grasses were heavily grazed, with up to 98% of what was potentially available in the control paddock being consumed by the time of the first pasture assessment. There were marked similarities between Muller and the DPI paddock for utilisation of *Enneapogon spp*., indicating cattle grazing, alone, was responsible for utilising such a high proportion of this pasture grass. In May 2000, under excellent seasonal conditions, Muller and DPI paddocks had less than 20% of the *Enneapogon* that was available in the control paddock.

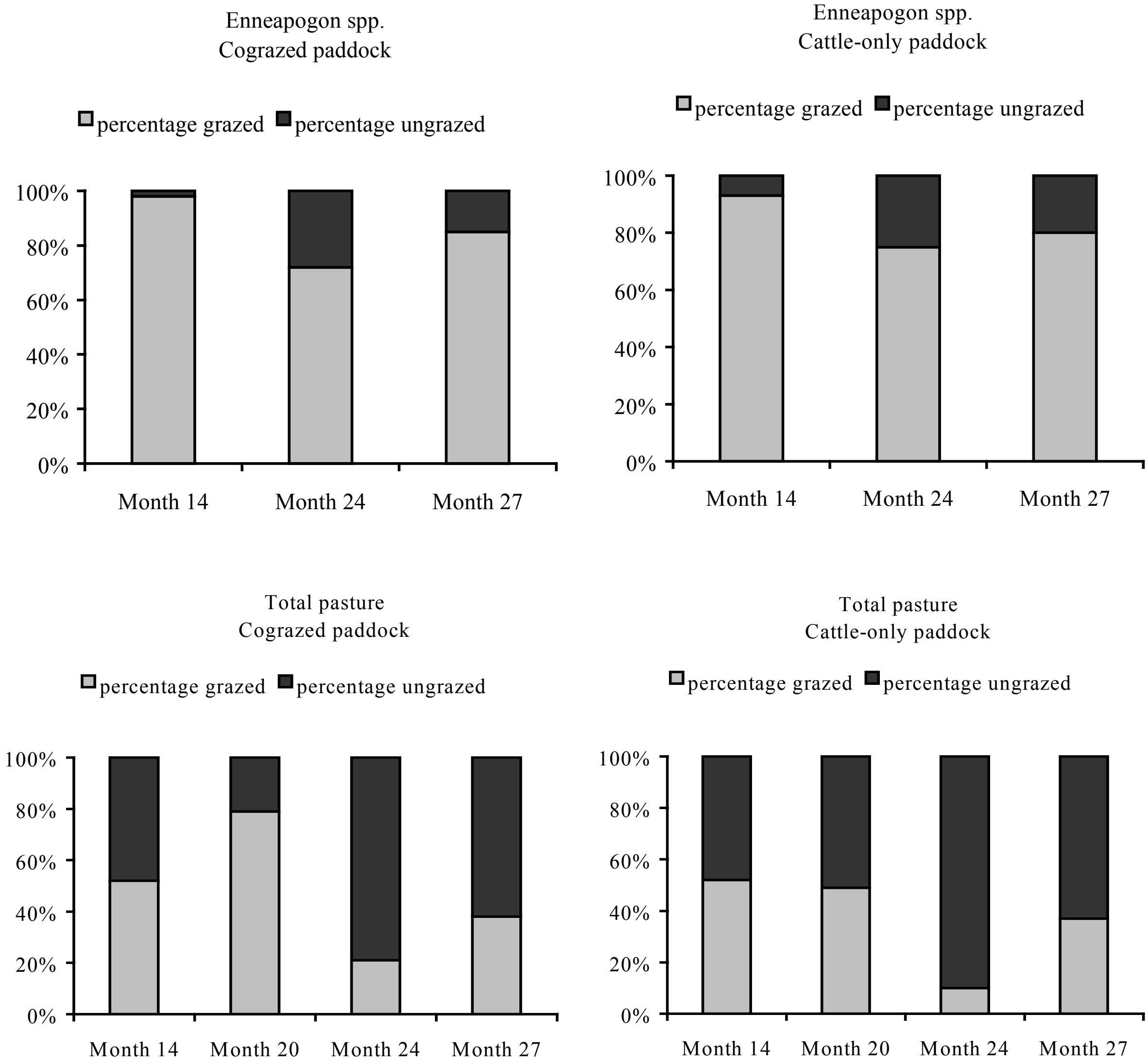


Figure 9. Percentage of total pasture and of *Enneapogon spp*. utilised in the cattle only DPI and cograzed Muller paddock at each pasture assessment.

Pasture quantity

Figure 10 shows the level of accuracy achieved for the visual estimation of pasture quantities. It shows that satisfactory performance of visual estimation techniques was achieved and that visual estimate data was a reasonable approximation of actual pasture species yields.

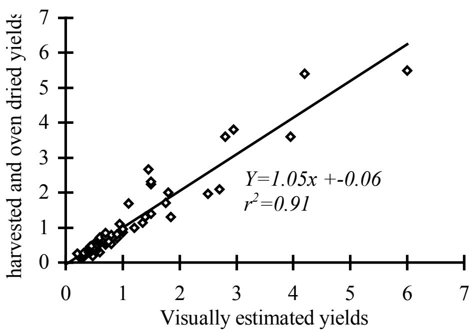


Figure 10. Linear regression for adjusting visual estimates of yield. Combined calibrations from April and October 1999. Data represents the field estimates of 45 x $1m^2$ quadrats which were then harvested to near ground level, oven-dried, and weighed.

The results of pasture yield assessments, in Table 5 below, show a large number of highly significant (*p<0.001*) differences between treatments. In most cases the control paddock is the treatment differing from the other 'stocked' treatment paddocks. This would be expected as the difference reflects the impact of grazing versus no (or minimal) grazing. However there were also significant (*p<0.05*) differences recorded between the cograzed Muller paddock and the DPI paddock for 'all forbs' on all sampling occasions and for total yield during the very dry conditions of October 1999. In these cases Muller paddock had significantly less pasture or less forbs than the DPI paddock.

Table 5. Average yield (kg/ha) for key pasture attributes as well as probability values based on one-way analysis of variance (p<0.05 rep=15, df=42). Those values in bold were not significantly different from each other based on comparison with the least significant difference (LSD) value.

Total pasture (all species)

Date	Muller paddock	DPI paddock	Control	*p value*
April 1999	**145**	**140**	293	*<0.001*
October 1999	32	77	150	*<0.001*
February 2000	**403**	**460**	**511**	*0.038*
May 2000	**930**	**940**	1487	*<0.001*

All forb species

Date	Muller paddock	DPI paddock	Control	*p value*
April 1999	8	24	70	*<0.001*
February 2000	60	**115**	**141**	*<0.001*
May 2000	162	**287**	**335**	*<0.001*

Perennial grasses

Date	Muller paddock	DPI paddock	Control	*p value*
April 1999	**130**	**105**	**146**	*0.291*
February 2000	**193**	**208**	**178**	*0.881*
May 2000	**433**	**272**	**522**	*0.069*

Annual grasses

Date	Muller paddock	DPI paddock	Control	*p value*
April 1999	**7**	**10**	77	*<0.001*
February 2000	**117**	**122**	175	*<0.001*
May 2000	**335**	**381**	630	*<0.001*

***Enneapogon spp*. grasses**

Date	Muller paddock	DPI paddock	Control	*p value*
April 1999	**1**	**3**	44	*<0.001*
February 2000	**28**	**25**	101	*<0.001*
May 2000	**54**	**71**	355	*<0.001*

Table 5 shows that total yield was significantly different for at least one treatment during all pasture assessments. However, it was only during the drought conditions of October 1999 that there was a difference between the stocked treatment paddocks. At this time the cograzed Muller paddock had less than half the total pasture of the DPI paddock and only 20% of the pasture available in the control paddock. After good rains in February 2000, the cograzed and DPI paddocks had very similar total pasture yields. On all occasions, the control paddock had significantly more pasture than the grazed treatment paddocks.

The results for ‘all forb species’ show that 14 months into the project there was significantly less weight of forbs in the cograzed pasture, compared to the other treatments. This large difference was maintained throughout the project and it is concluded that camels reduced the quantity of forbs when in a cograzed situation.

At no pasture assessment was there any difference ($p<0.05$) in the quantity of perennial grass in run-on areas, regardless of treatment. Cograzing had no impact on the availability of perennial grass to grazing cattle.

During all pasture assessments, there was no difference in the quantity of annual grass available in the cograzed or DPI paddocks. On all occasions, there was significantly more annual grass available in the control paddock, reflecting the utilisation level of annual grass by cattle in the grazed treatment paddocks. Cograzing had no impact on the quantity of annual grass available to grazing cattle.

Similarly during all pasture assessments, there was no difference in the quantity of *Enneapogon spp*. available in Muller or the DPI paddock. On all occasions, there was significantly more *Enneapogon spp*. available in the control paddock, reflecting the utilisation level of this important species in the grazed Muller and DPI paddocks. Cograzing had no impact on the quantity of *Enneapogon spp*. available to grazing cattle.

Relative frequency of key pasture species

Table 6. Percentage frequency of occurrence of key pasture attributes with sample size (n) and probability values based on chi-square analysis of 2x3 contingency tables. Where a significant difference (*p<0.05*) was recorded, Fisher's exact test for 2x2 contingency tables was used to show which treatments did not differ significantly (*p>0.05*) from each other, and these treatments are shown in bold type.

Salsola kali (buckbush)

Date	Muller paddock	DPI paddock	Control	*n*	*p value*
April 1999	**0**	**0**	10	*540*	*n/a*
October 1999	**1**	**3**	**3**	*270*	*0.648*
February 2000	**1**	**1**	12	*495*	*<0.001*
May 2000	**5**	**1**	20	*315*	*<0.001*

Sclerolaena spp. (copperburrs)

Date	Muller paddock	DPI paddock	Control	*n*	*p value*
April 1999	0	**2**	**3**	*540*	*0.015*
October 1999	**32**	60	**27**	*270*	*<0.001*
February 2000	**21**	44	**23**	*495*	*<0.001*
May 2000	14	**48**	**50**	*315*	*<0.001*

Sida platycalyx (lifesaver burr)

Date	Muller paddock	DPI paddock	Control	*n*	*p value*
April 1999	8	**32**	**24**	*540*	*<0.001*
October 1999	**47**	63	**34**	*270*	*<0.001*
February 2000	**12**	**18**	4	*495*	*<0.001*
May 2000	39	62	11	*315*	*<0.001*

All forb species

Date	Muller paddock	DPI paddock	Control	*n*	*p value*
April 1999	16	58	68	*540*	*<0.001*
February 2000	**61**	78	**64**	*495*	*0.001*
May 2000	**95**	**90**	**89**	*315*	*0.157*

Enneapogon spp. (oat grasses)

Date	Muller paddock	DPI paddock	Control	*n*	*p value*
April 1999	4	13	61	*540*	*<0.001*
October 1999	**4**	**7**	**5**	*270*	*0.797*
February 2000	**40**	**45**	67	*495*	*<0.001*
May 2000	**35**	**49**	**50**	*315*	*0.064*

Table 6 shows that *Salsola kali* (buckbush) was rarely encountered in either of the stocked paddocks, remaining uncommon even after it increased in the control paddock after good rains in May 2000. At this time it was found in one in five samples in the control paddock but only in one in 20 samples from the cograzed paddock. There were no significant differences in the frequency of occurrence of *Salsola kali* attributable to cograzing, but grazing either by cattle, or by both cattle and camels, did impact on this species.

The results for *Sclerolaena spp*. (copperburrs) show that none were encountered in the cograzed paddock during the first pasture assessment, but that at the time, they were in low numbers in the other treatments as well. By October 1999, there were similar frequencies of *Sclerolaena spp*. in the cograzed and control paddocks, but there was significantly more frequent occurrence of these plants in the DPI paddock. This trend continued after good rains in February 2000. However, by May 2000 there was a reversal, with significantly less *Sclerolaena spp*. being recorded in the cograzed paddock than in either of the other paddocks.

On all occasions there was a highly significant difference in the frequency of occurrence of *Sida platycalyx* (lifesaver burr). However, only at the first pasture assessment could this difference be attributed to cograzing. During drought conditions in October 1999, there was significantly more *Sida platycalyx* in the DPI paddock, but by February 2000, both cograzed and DPI paddocks had similar numbers of this species. In May 2000 there was significant differences between all treatments, with the control paddock having by far the least numbers of *Sida platycalyx.*

The results show that after 14 months, there were significantly less numbers of forbs of all species in the cograzed paddock, but at all pasture assessments thereafter, there were no differences that could be attributed to cograzing.

The frequency of occurrence of the key grass pasture species *Enneapogon spp*. (oat grasses) was significantly lower in the cograzed paddock by April 1999 of the project. During the ensuing drought conditions, all treatment paddocks had little *Enneapogon spp*. At February 2000 *Enneapogon* was occurring in nearly half of all samples in both cograzed and DPI paddocks, but was significantly more common again in the control paddock. By May 2000, with continued grass growing rains, *Enneapogon spp*. were frequent over all treatments and there were no significant differences regardless of whether a paddock was grazed or not grazed.

Ground Cover of Plants and Plant Litter

Figure 11 shows that visual estimates of percentage cover made in the field were not very well correlated to those made by taking vertical photographs and then estimating cover by a 64-dot grid overlaying each photographic print.

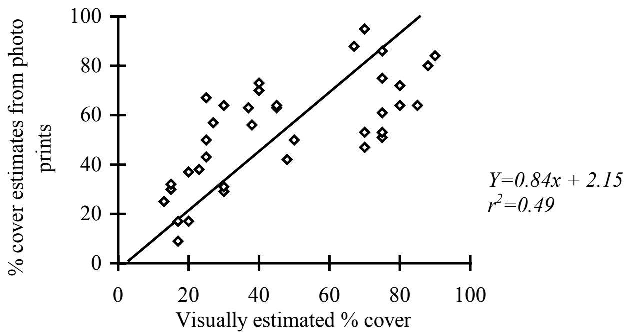


Figure 11. Linear regression for percentage cover estimates made in the field against cover estimates made of the same 37 quadrats using vertical photographs and a 64-dot grid overlying the photographic print. Combined calibrations from October 1999 and February 2000.

Table 7. Percentage of sampling plots within each cover class, with sample size (n), and probability values based on chi-square analysis (2x3 contingency tables) of frequency in each cover class. Where a significant difference (*p<0.05*) was recorded, Fisher's exact test for 2x2 contingency tables was used to show which treatments did not differ significantly (*p>0.05*) from each other, and these treatments are shown in bold type.

Run-off land type October 1999.

Cover Class	Muller paddock	DPI paddock	Control	*n*	*p value*
0-10%	93	81	67	*268*	*< 0.001*
11-20%	**7**	**11**	**11**	*268*	*0.470*
21-30%	0	**3**	**10**	*268*	*0.001*
> 30%	0	**5**	**11**	*268*	*<0.001*

Run-off land type February 2000.

Cover Class	Muller paddock	DPI paddock	Control	*n*	*p value*
0-20%	**24**	**22**	**18**	*270*	*0.536*
21-30%	**33**	**32**	**22**	*270*	*0.187*
31-40%	**23**	**19**	7	*270*	*0.011*
41-50%	**11**	**12**	**10**	*270*	*0.893*
51-70%	**7**	**9**	19	*270*	*0.028*
71-100%	**1**	**6**	23	*270*	*< 0.001*

Run-on land type October 1999

Cover Class	Muller paddock	DPI paddock	Control	*n*	*p value*
0-10%	**38**	**31**	**23**	*271*	*0.097*
11-20%	**13**	**19**	**11**	*271*	*0.306*
21-30%	**11**	**8**	22	*271*	*0.016*
31-40%	**8**	**11**	**7**	*271*	*0.537*
41-60%	**10**	**11**	**17**	*271*	*0.382*
61-80%	**7**	**9**	**7**	*271*	*0.804*
81-100%	**13**	**11**	**14**	*271*	*0.805*

Run-on land type February 2000

Cover Class	Muller paddock	DPI paddock	Control	*n*	*p value*
0-20%	**17**	**20**	**10**	*237*	*0.198*
21-30%	**6**	**15**	**10**	*237*	*0.142*
31-40%	**11**	**9**	**10**	*237*	*0.923*
41-50%	**7**	**13**	**15**	*237*	*0.169*
51-60%	**14**	**9**	**7**	*237*	*0.280*
61-70%	**16**	**9**	**11**	*237*	*0.453*
71-80%	**8**	**12**	**11**	*237*	*0.218*
81-100%	**22**	**12**	**21**	*237*	*0.185*

Table 7 shows that, in the run-off land type, in the drought conditions of October 1999, there were significantly more (*p<0.05*) sampling plots in the cograzed paddock with 0-10% cover than in the other paddocks. No samples in the cograzed paddock had greater than 20% cover, whereas 11% of samples taken from the control paddock had cover greater than 30%. These results show that, during drought conditions, cograzing may leave more of the soil surface bare than cattle grazing alone.

After significant rains in February 2000, any increase in bare soil caused by cograzing during the drought conditions was reversed for the run-off land type. There were no significant differences between cover in the cograzed and DPI paddocks. However, there were significant differences between the stocked paddocks and the control paddock. The control paddock had greater frequency of samples with higher percentage cover (> 50% cover), indicating that both grazing treatments increased the percentage of ground covered with bare soil.

In run-on land types, where there is more leaf-fall from trees and shrubs, and where there are more persistent perennial grasses, there were no significant differences across treatments for percentage ground cover, even under the drought conditions of October 1999. There was one cover class (21-30%) that had significantly higher frequency in the control paddock.

After good rains in February 2000, there were still no significant differences in percentage ground cover between any treatments for the run-on land type.

Cattle and camel production measurements

1998/99 Steer and camel performance
In 1998/99 the breeder herd of camels were cograzed with steers in Muller paddock. Steer entry weights in mid-March 1998 were 277 ± 4.4 kg (mean ± standard error) and 273 ± 4.5 kg into Muller and DPI paddocks. Their final weights were 428 ± 5.8 kg and 416 ± 5.8 kg in mid-February 1999. Steer weight gains were 151.2 ± 3.7 kg in Muller paddock and 137.4 ± 3.4 kg in the DPI paddock for the period. The difference in weight gain approached but did not achieve significance ($p = 0.05$). Steers in Muller paddock gained an average of 445 ± 11 grams per day whilst steers grazed in the DPI paddock gained 407 ± 10 g/day.

Growth profiles of the two steer groups are presented in Figure 12 below. Maximum steer growth rates were in the March to June period when steers in Muller paddock gained 733 ± 32 g/day and steers in the DPI paddock gained 662 ± 34 g/day. Minimum steer growth rates were in the November to February period when steers in Muller paddock gained 255 ± 25 g/day and steers in the DPI paddock gained 172 ± 22 g/day.

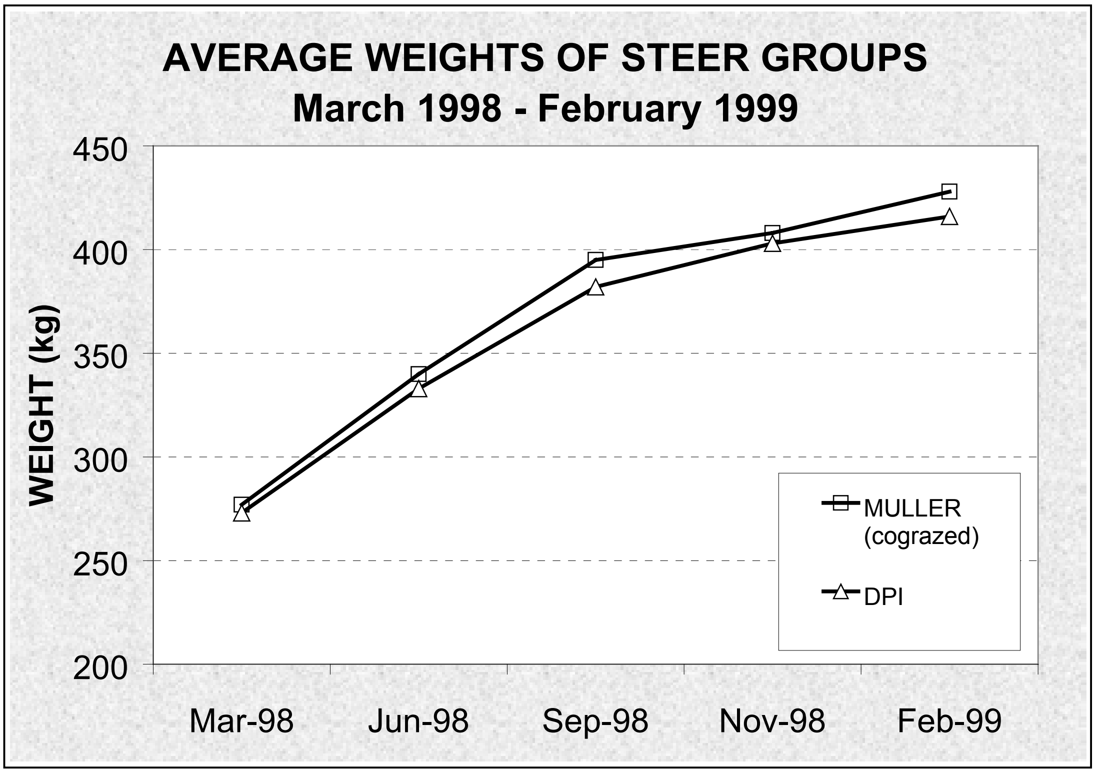


Figure 12. Average steer weights from March 1998 to February 1999

Camel liveweights fluctuated for most classes during the 12 month period that the breeding herd was cograzed in Muller paddock. Liveweights and liveweight changes for the classes of camels in the breeder herd between March 1998 and March 1999 are shown below in Table 8.

Table 8. Average camel weights and weight changes by class between March 1998 and March 1999.

Camel class		15/3/98	8/6/98	7/9/98	30/11/98	8/3/99
Bull	Weight (kg)	664	590	550	655	610
	Change since last weight (kg)		-74	-40	105	-45
Cows*	Weight (kg)	462 ± 14.6	410 ± 19.5	467 ± 17.3	459 ± 9.9	470 ± 12.1
	Change since last weight (kg)		-57 ± 19.2	68 ± 16.1	-8 ± 14.1	11 ± 6.6
96 born calves	Weight (kg)	343 ± 13.5	326 ± 10.7	360 ± 12.0	Removed from Muller pdk	
	Change since last weight (kg)		-16.4 ± 7.3	33.6 ± 7.0		
97 born calves*	Weight (kg)	182 ± 8.7	224 ± 6.8	283 ± 6.0	320 ± 10.2	345 ± 11.4
	Change since last weight (kg)		42 ± 2.6	53 ± 3.3	47 ± 4.4	25 ± 5.4

* Not all of the camel cows and calves were trapped and weighed on every occasion. Weight changes were calculated only for those individuals weighed on consecutive occasions hence weight changes added to average weights do not always appear to be correct.

The bull camel's weight fell during the cooler months between March and June and again between June and September, coinciding with when he was showing obvious signs of rut. He then recovered to close to his March weight by November 1998. He showed no obvious signs of rut in March 1999, however his weight had fallen again.

Camel cow and pre-pubescent male camel weaner weights fell from March to June, coinciding with when the bull was in rut. By September, the cows weighed in June had regained to their March weights and they remained relatively constant afterwards. By September, the 1996 born male camel weights exceeded their March weights. The 1997 born camel calf weights continually rose throughout the year. These calves gained 164 ± 7.8 kg at an average of 457 ± 22 g/day over the year.

1999/2000 Steer and camel performance

In 1999/2000 young bull camels were cograzed with steers in Muller paddock. These steers were lighter than those used in the previous year. Seventeen steers were swapped between the two paddocks after three months to give four groups of steers. Steers were paired on the basis of liveweight and then swapped. The four groups and their initial and final liveweights were:

1. Always cograzed in Muller paddock, (255 ± 8.3 to 434 ± 9.9 kg);
2. Swapped from Muller paddock to the DPI paddock, (264 ± 5.9 to 440 ± 11.2 kg);
3. Swapped from the DPI paddock to Muller paddock, (262 ± 6.7 to 440 ± 9.0 kg);
4. Always in the DPI paddock, (240 ± 4.1 to 409 ± 4.8 kg).

Growth profiles of the four groups were compared to try to ascertain if paddock differences lead to production differences. At intervals over the 13 month period from March 1999 until April 2000 there were significant differences in weight gains between groups as shown in Table 9 below. Significant differences only occurred after the two groups of steers were swapped between paddocks. Steers swapped into the DPI paddock gained least weight in their first three months (May to August) in the DPI paddock, significantly less than both groups in Muller paddock. In the next four months (August to January) steers swapped into the DPI paddock gained significantly more weight than both groups in Muller paddock. Both groups of steers in the DPI paddock gained significantly less weight than the group swapped from the DPI paddock into Muller paddock in the final three months between January and April. However, when compared over the entire 13-month period there were no significant weight gain differences between any of the four groups.

Table 9. Weight gains (kg) and Average daily gains (g/day) of the four steer groups and bull camels. Different letters beside weight gains within the same column denote significant differences between steer groups.

	1/3/99 – 24/5/99	24/5/99 – 30/8/99	30/8/99 – 3/1/00	3/1/00 – 2/4/00	1/3/99 – 2/4/00
Always in Muller paddock	30.3 ± 3.1a 352 ± 36	18.8 ± 3.8c 192 ± 39	58.8 ± 5.9a 466 ± 47	71.9 ± 7.3ab 799 ± 81	180.0 ± 8.0a 452 ± 20
Swapped Muller to DPI	23.2 ± 3.5a 284 ± 46	5.4 ± 3.0a 144 ± 47	79.2 ± 4.4b 458 ± 40	64.3 ± 5.6a 905 ± 55	176.6 ± 5.9a 444 ± 15
Swapped DPI to Muller	24.4 ± 3.9a 270 ± 41	14.1 ± 4.6bc 55 ±30	57.6 ± 5.0a 628 ± 35	81.5 ± 5.0b 715 ± 62	177.6 ± 6.7a 446 ± 17
Always in DPI paddock	24.3 ± 1.8a 283 ± 21	10.1 ± 1.5ab 103 ± 15	70.3 ± 2.9ab 558 ± 23	64.6 ± 2.8a 718 ± 31	166.7 ± 3.4a 422 ± 9
Bull camels in Muller paddock	25.0 ± 3.6 291 ± 42	8.9 ± 3.3 91 ± 34	88.3 ± 10.9 685 ± 84	-58.3* -648	63.9* 159

* Standard errors could not be calculated because the camels' identification collars had been removed.

Weight gains of the young bull camels were quite similar to that of the steers from March 1999 until January 2000, and then fell dramatically between January and April. Similarly to cattle, the young bull camels exhibited their fastest growth rates after rain when forbs were available.

Growth profiles of the four steer groups are shown in Figure 13 below.

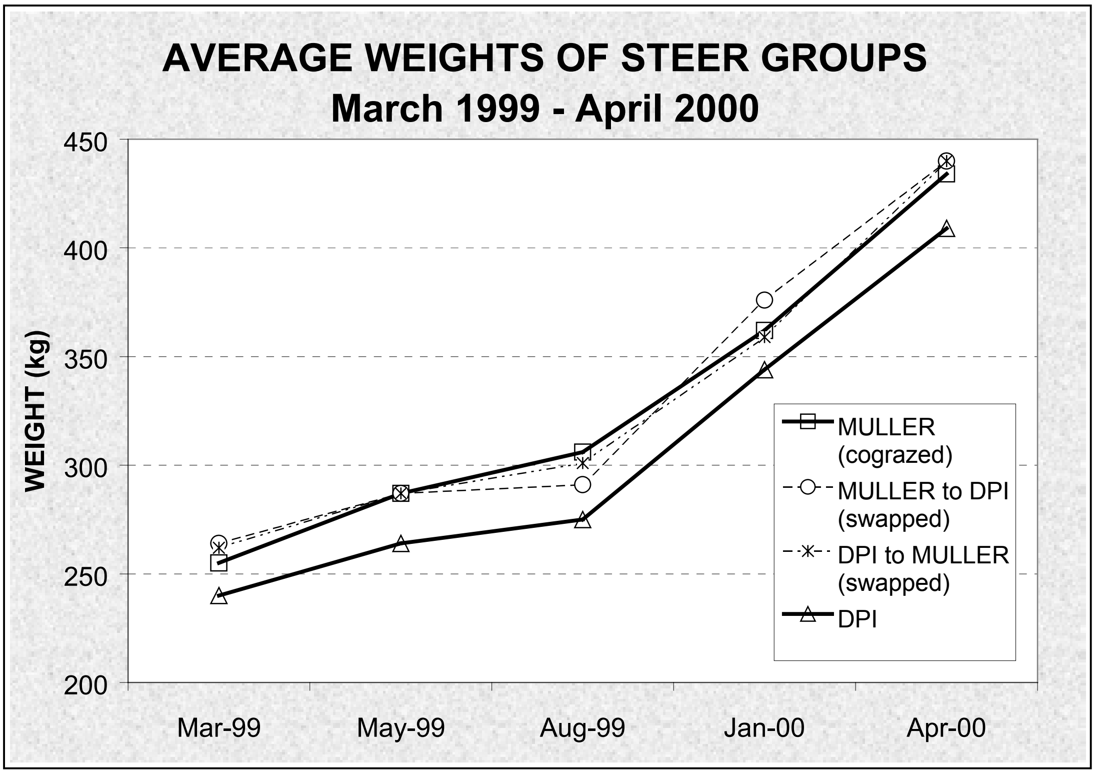


Figure 13. Average weights of steer groups from March 1999 to April 2000.

Maximum steer growth rates were in the January to April 2000 period and minimum steer growth rates were in the May to August 1999 period.

2000/2001 Steer and camel performance
Between August 2000 and April 2001 steers were cograzed with camels in the DPI paddock. Wet weather reduced the amount of information collected to beginning and final weights. Steers in Muller paddock initially weighed 292 ± 5.8 kg and their average final weights were 452 ± 6.5 kg. Steers in the DPI paddock initially weighed 296 ± 3.5 kg and their average final weights were 443 ± 3.6 kg. Steers in Muller paddock gained 160 ± 5.0 kg, significantly more than steers in the DPI paddock that gained 146 ± 3.4 kg ($p = 0.05$). Average daily gains for the two groups were 635 ± 20 and 581 ± 14 g/day.

During this period the young bull camels gained 109 ± 6.3 kg from their initial average weight of 395 kg to their final average weight of 505 kg. Their average daily gains were 414 ± 24 g/day.

Total livestock productivity
Livestock maintenance and production from cograzing and grazing cattle only were recorded using the livestock weight maintained and produced per square kilometre. In 1998/99 camel production from the breeder herd resulted from the growth of young camels. In the other two years camel production was from the growth of young bull camels and was derived similarly to that for steers. Livestock maintenance and production data for cattle and camels in Muller paddock and for cattle in the DPI paddock is presented in Table 10 below.

Table 10. Livestock weight (kg/km^2) maintained and produced in the two paddocks in each period with proportional cattle and camel maintenance and production components shown in brackets for cograzing.

Period	Species	DPI Paddock livestock weight (kg/km^2)		Muller Paddock livestock weight (kg/km^2)	
		Maintained	Produced	Maintained	Produced
March 98	Steers	995	440	1155 (48%)	630 (72%)
–	Camels			1265 (52%)	245 (28%)
March 99	**Total**	**995**	**440**	**2420**	**875**
March 99	Steers	900	570	1080 (72%)	635 (90%)
–	Camels			415 (28%)	70 (10%)
April 00	**Total**	**900**	**570**	**1495**	**705**
August 00	Steers	1077 (74%)	532 (84%)	1218	667
-	Camels	378 (26%)	104 (16%)		
May 01	**Total**	**1455**	**636**	**1218**	**667**

Muller paddock maintained more steer liveweight per square kilometre by virtue of the higher stocking rate. Muller paddock maintained 16%, 20% and 13% more kg/km^2 in each period. Muller paddock also produced more steer liveweight per square kilometre. The higher levels of production were 43%, 11% and 25% more kg/km^2.

During the year March 1998 to March 1999 steers accounted for 48% and the breeder herd of camels accounted for 52% of the livestock weight maintained in Muller paddock. Compared to the DPI paddock, the cograzed Muller paddock:
- maintained 243% more livestock weight per square kilometre (2420 versus 995 kg/km^2),
- produced 199% more livestock weight per square kilometre (875 versus 440 kg/km^2).

As Table 10 shows, steer growth contributed 72% of the total livestock production obtained during the period.

During the 13 months from March 1999 to April 2000 steers accounted for 72% and the young bull camels accounted for 28% of the livestock weight maintained per square kilometre in Muller paddock. Compared to the DPI paddock, the cograzed Muller paddock:
- maintained 66% more livestock weight per square kilometre; and,

- produced 24% more livestock weight per square kilometre.

Steer growth contributed 90% of the total livestock production obtained during the period.

During the 8 months from August 2000 to May 2001 steers accounted for 74% and the young bull camels accounted for 26% of the livestock weight maintained per square kilometre in the DPI paddock. Cograzing the DPI paddock from August 2000 until May 2001 resulted in the DPI paddock:

- maintaining 19% more livestock weight per square kilometre than Muller paddock; and,
- producing 5% less liveweight per square kilometre.

Steer growth contributed 84% of the total livestock production obtained during the period.

5. Discussion of Results

Camel feeding and behavioural observations

Camels are mainly leaf and forb eaters with an extremely wide food spectrum. Generally they are very flexible with their food selection. They usually select the freshest or most frequently growing plants, but show preferences regardless of the supply. In contrast to most other herbivores that are native to Australia or have been imported, camels are able to reach food plants up to 3.5 meters high. They can also utilise areas that many other native, feral and domestic animals in Australia cannot reach because of their high mobility, being less dependent on water and the variety of plants they eat. Dicotyledons (broad-leaved plants) can make up to 97% of the camels' diet. Grasses are of some importance only after rainfall following a dry period until forbs become available.

Rainfall patterns in Central Australia are extremely variable. Therefore food availability is irregular and seasonal feeding preferences of camels are impossible to define, except that in dry periods they mostly utilise shrubs and trees and in wet periods they eat grasses for a short period and then forbs, after they become available.

Long term studies at Newhaven station have shown that food selection by camels is strongly related to the amount of precipitation (Dörges, Heucke, 1995). The same basic pattern was observed with the food selection of the camels at Waite River. A statistical correlation analysis however was not attempted as the observation periods were not continuous throughout the year.

The feeding behaviour of camels is adapted to desert conditions. Camels continually walk while eating and usually take one bite every few steps. The less food available the larger the distance between camels. Free ranging camels are therefore not likely to contribute to overgrazing, except on highly preferred species. In paddocked situations however the density is crucial and in dry times some damage to preferred shrubs and trees will occur.

The observed group formation and social behaviour of the camels at Waite River corresponded quite well with that of free ranging camels:

- Camels are social animals, living in non-territorial groups;
- Cow groups consist of cows and their calves and occur only during summer, outside the breeding season;
- Breeding groups consist of several cows with their calves herded by a dominant bull during the rutting season between April and September; and,
- Surplus bulls live in bachelor groups that occur throughout the year and consist of bulls of all age classes. Elderly bulls tend to live solitarily.

In winter the majority of the adult bulls are in rut and cow groups are monopolised by a bull. The bull chases away all young bulls, whereas young cows remain in the group. The young males join other bachelors, forming loose associations. The tenure of a cow group is three to six months and is terminated voluntarily or by a stronger bull. During the summer, cow groups remain on their own or they are escorted by younger and/or weaker bulls.

Camels are seasonal breeders, the majority of the births are between June and November. Before parturition cows segregate and give birth in seclusion. They live alone for up to three weeks, then cow and calf join up with other new mothers, forming new "kindergarten" groups which are subsequently stable for 1.5 to two years, until the young are weaned. In one study in Central Australia, 93% of calves were born between June and November and birth intervals were about two years (Dörges and Heucke, 1989). The gestation period of feral camels is about 12 months and birth intervals are 18 - 24 months. Death of newborn calves results in decreased birth intervals. If her calf dies, the cow has a fertile oestrus after approximately three weeks. Bull camels in rut show aggressive behaviour toward newborns which results in infanticide. This behaviour is similar to that in stallions (Duncan 1982) and enhances the reproductive success of the infanticidal bull, because the calf is usually unrelated to the bull. The cows segregate themselves before birth as a strategy against infanticide.

Although the bull of the breeding group was the only adult male in Muller paddock he showed adaptive strategies to maximise his reproductive success. By herding those female groups which had 1 year old calves, he maximised his successful mating chances as camel cows generally only have a calf every second year. This bull stayed with the females all year round and did not leave them voluntarily. This unusual behaviour was obviously caused by the artificial situation with no other adult males in the vicinity and the small size of the paddock.

The death of the calf from the single cow living with nine bulls in Muller paddock in 1999/2000 was most likely due to infanticide. Aggressiveness towards newborns is not only shown by adult bulls in rut but also by sub-adult bulls. The single mother would have had no chance of escaping the nine sub-adult bulls in such a small paddock. To establish functional breeding groups in paddocks this has to be taken into consideration.

The release of the 20 young bulls into DPI paddock created a unique situation that had not been observed before. Normally young bulls, when joining bachelor groups, associate with at least one or more older, experienced males. It takes usually a long period of time until young bulls show signs of dominance, as they are obviously suppressed by the elder males. The observed early dominance behaviour may have negative consequences on the weight gain of the individuals.

Tree and shrub impact monitoring

Canopy cover decreased most in the first year of the study. The camels were put into an area that had had no camel browsing for at least 40 years and minimal cattle browsing for 10 years. Therefore trees and shrubs had full canopies and the camels' preferred food plants were easily accessible. In addition, 1996 was the driest year of the observation period, so with an initial density of approximately two camels per square kilometre a substantial decrease in crown cover was expected. The changes in canopy cover in the cograzed paddocks that followed were a function of camel stocking rates and the climatic conditions.

On the comparative transects outside Muller paddock the changes in crown cover were influenced by the seasons. Except for during the dry period in 1999, no cattle browsing was recorded on the comparative transects. The obvious decrease in crown cover outside Muller paddock in 1999 was also caused by the death of many *Senna* and *Eremophila* shrubs during the dry period.

The browsing pressure indices calculated reflect the general impressions gained at the time of assessment very well. Maximum browsing pressure at Waite River was on *Santalum lanceolatum* (Plumbush). The unexpectedly high use of plumbush even under the best seasonal conditions raises concern for the survival of this species in paddocks where camels are kept permanently. Of somewhat less concern is *Ventilago viminalis* (supplejack). This species was only lightly affected in the DPI paddock under the good seasonal conditions and the low density of camels. However in Muller paddock Supplejack was under severe pressure.

Although *Acacia estrophiolata* was one of the main food plants in Muller paddock, browsing pressure was moderate because this species was also the most abundant. Ironwood is locally very common and in some areas in Central Australia young ironwood is considered a 'woody weed'. To reduce young ironwood with camels would probably require higher camel densities and browsing extended over a longer period of time. Other plant species preferred by camels would be likely to suffer heavily under such conditions.

Acacia farnesiana and two other introduced undesirable woody species *Acacia nilotica* (prickly acacia) and *Parkinsonia aculeata* (parkinsonia) can develop impenetrable thickets in some areas. Because camels favour these prickly bushes, a control on these species can be achieved. In Muller paddock *Acacia farnesiana* had virtually disappeared and did not recover while the camels were kept there.

This component of the project successfully met project objectives 2 and 3, by improving knowledge of the impact of camels on native vegetation and woody weed species in Central Australia.

Pasture plants, pasture utilisation and ground cover

The impacts described on ground vegetation were the result of 27 months of the imposed grazing treatment. This was not long enough to expect changes in pasture composition, because much of the future pasture potential remained dormant in the seed bank. It has been shown in Central Australia that permanent change to vegetation as a result grazing can take much longer time frames than was possible in this study (Foran *et al* 1986; O'Reilly 1998).

The results confirmed the expectation that cograzing would not hinder cattle production through competition for pasture grasses. The most important of the grasses in the study area are *Enneapogon spp.* because of their nutritional qualities and widespread occurrence after summer rains. Cograzing had no impact on these species (*E. polyphyllus*, with smaller amounts of *E. avenaceus*), or on other common annual grasses like *Aristida contorta*. Perennial grasses, important for cattle maintenance in drier periods, were also unaffected by cograzing.

Perennial grasses are a feature of the run-on land type in the study area and these fertile patches, with more perennial grasses and larger shrubs and trees, appear to be the most resilient to cograzing. The percentage of ground covered by bare soil compared to plants and plant debris was only affected by cograzing in the run-off land type of annual grasses and sparser shrubs. Even then, this was only during the very dry conditions of October 1999, and the cograzed Muller paddock soon had as much cover as the DPI paddock, once summer rains had produced new growth.

The calibration of visual estimates of cover was not successful during the project. The reasons why are not clear, but it is suspected that pin size (dot size) might be partly responsible. In theory, because a pin (or dot) has position, but no area, workers have tried to use the smallest sized pins possible to reduce the error associated with having any diameter of pin or dot (Levy & Madden 1933; Cunningham 1975). For example, it was found that a pin diameter in the field of 2.4 mm gave higher than expected basal cover of American bunchgrasses (Johnston 1957). The method of Wilkie (1997) used in this project has no specifications for dot sizes. A clear acetate sheet with dots drawn by a felt tip marker was used (average diameter = 1 mm). If the photograph and dot grid were scaled up to field size, the dots used to measure cover would be 12 mm in diameter, far greater than any worker using similar methods has employed. Having said that, there was no particular bias in the calibrations, with both overestimating and underestimating occurring. For these reasons, the results showing differences in percentage ground cover need to be treated cautiously.

Cograzing did impact repeatedly on the total quantity of forbs available, yet the frequency data shows that this did not always translate into number of forbs in a given area. The exception was for *Sclerolaena spp*. during May 2000. These results indicate that camels were grazing forbs, thereby making individual plants smaller, however this was yet to translate into a change to botanical composition. The fact that there was a botanical composition change for *Sclerolaena spp*. by May 2000 indicates that if the treatments had have been in place for longer, more definite changes to botanical composition of forbs may have resulted from cograzing.

The impact of camels on the quantity of forbs available was demonstrated in relatively thickly wooded vegetation in Central Australia. The impact on forbs may be even greater in areas where there are less trees and shrubs. The consequences of having fewer forbs in a pasture were not identified by this project. It is unknown if a reduction of forbs leads to an increase in grass. In pastures where forbs predominate, such as when summer rains fail and winter rains follow, there may be more competition between camels and cattle.

Summer growing forbs like tar-vines (*Boerhavia spp*.) that are preferred by both cattle and camels may also be affected by cograzing. However their growth was too ephemeral, and they had often decayed by the time of the pasture assessments undertaken a few weeks after rain.

Squires & Siebert (1983) found that Central Australian free-ranging steers grazed a high proportion of grasses, either when green or dry. However forbs were always a component of the diet while they were present. At one stage as green grasses were drying out, forbs contributed 20% to the steers' diet (presumably because the forbs still held some moisture). After 5 months without rainfall, cattle began browsing trees and shrubs at up to 20% of their diet. Dry grasses made up the rest of the diet at this time. There is little published information on how important forbs are to cattle production in Central Australia or even what species are preferentially grazed. There is more documented about forb dietary preferences of camels, than of cattle (eg. Dörges & Heucke 1995).

There is anecdotal information about some species of forbs that cattle prefer, and the results for *Salsola kali* support the theory that this species is favoured by both cattle (younger succulent plants only) and camels. It is expected that this species would be suppressed under cograzing.

The results on the level of pasture utilisation show that even when stocking rates are carefully set, the seasons are the dominant factor determining pasture utilisation. In particular, it was clear during the drought conditions of October 1999 that the stocking rates were not going to be sustainable if the drought persisted. While a commercial operation might have to re-adjust stocking rates at these times, it was useful to the project that these drought conditions were experienced. Greater impacts resulting from having more large animals in a given area would be expected in times of drought than under better seasonal conditions. At these times, when preferred species are not available, there may be more overlap in the diets of the two species, particularly for palatable trees and shrubs, and extra trampling may increase the amount of bare ground. While these impacts may or may not have developed if the drought had continued during the project, it was fortunate for the Central Australian cattle industry that good summer rains began soon after in 1999/2000.

The rapid change in Central Australia that results from good summer rains is clearly shown by the recovery of pastures across all treatments after February 2000. By May 2000, (only 7 months after the drought), *Enneapogon spp*. were as frequently encountered in the grazed paddocks as in the control paddock. However there was a dramatic difference in the quantity of *Enneapogon spp*. available in the control paddock, demonstrating the preferential grazing of these species by cattle. Percentage utilisation of *Enneapogon spp*. was always much higher than for total pasture. Ungrazed tussocks of these grasses in the control paddock were able to persist and revive after rains, but the grazing and trampling in the stocked treatment paddocks during the drought, meant that these grasses had to grow back mostly from seed after the good rains. It is also possible that the control paddock has inherently more *Enneapogon spp*. because of very conservative grazing practices since 1972. Although detailed pasture assessments were not undertaken in 2001, further increase in *Enneapogon spp*. in response to the second successive good season was observed.

The pasture assessments in the project showed that cattle producers do not need to be overly concerned about camels and cattle competing for pasture in wooded country of Central Australia, should they wish to cograze camels with established cattle herds. It can be expected that there would be less quantity of forbs available in cograzed paddocks, but that grass production would be the same as in a paddock stocked with cattle only.

This component of the project met project objective 4, by obtaining objective data on pasture utilisation under cograzing compared to cattle grazing.

Cattle and camel production measurements

Cattle production

Cograzing with camels did not appear to limit steer weight gains during the periods from March 1998 to February 1999 or from March 1999 to April 2000. Presumably they did not compete for feed resources or have any other interactions that were detrimental to production through a range of seasonal conditions. The profiles of the steer growth curves during the two periods were opposite in shape, a clear response to seasonal and pasture conditions. Average daily gains during both periods were quite similar over the entire periods, despite the different growth patterns. Average daily gains ranged from a minimum of 407 g/day to a maximum of 452 g/day.

The fact that none of the four steer groups had significantly different weight gains over the 13 month period from March 1999 to April 2000 indicated that there was no large underlying productivity difference in terms of potential steer weight gains between the two paddocks during that period. When compared to steer groups that were in Muller and the DPI paddock all along, steers swapped into these paddocks had weight gains approximately five kilograms lower over the three months from May to August 1999. Even though the steers were only swapped into adjoining paddocks and they were both very small paddocks by regional standards, their weight gains showed that they took more than three months to adjust to their new paddocks. The effect was greatest on the steers swapped into the DPI paddock, where a contributing factor was that many of them 'hung' in a dry corner and had to be taken back to the water point soon after being swapped. Between August 1999 and January 2000 the steers swapped into the DPI paddock showed compensatory weight gain and had the highest weight gain, significantly higher than either group in the cograzed Muller paddock. This compensatory weight gain evened up the weight gains of the different groups, and as a result no group had a significantly different weight gain from any other over the 13 months.

The fact that there was no weight gain difference in steers that were cograzed in Muller paddock in the first two years raised the following question. Was Muller paddock a more productive paddock but had cograzing camels with steers limited their productivity? This possibility was further investigated by cograzing the DPI paddock from August 2000 until April 2001 during the final year of the project.

The final eight months steer growth information showed that steers in Muller paddock gained significantly more weight than steers in the DPI paddock. However the average daily weight gain advantage of 54 g/day in this period was only marginally higher (16 and 24 g/day, giving an average difference of 20g/day higher daily gain) than the difference in favour of Muller paddock in the two earlier years. This finding is believed to have been due to the combination of excellent seasonal conditions and different land types, rather than any impact of reversing the grazing regimes. There are minimal areas of sloping country and no externally draining watercourses in Muller paddock whereas the DPI paddock has a relatively high proportion of sloping country that runs into an externally draining watercourse, hence more water is available for pasture growth in Muller paddock. If the difference detected in steer average daily gains could be attributed to cograzing with camels, a reduction in the order of 10 g/day in steer growth rates equates to less than four kg per year. More intensive studies would be necessary to detect such subtle differences in steer growth rates under cograzing, if they exist. This result needs to be interpreted considering the steer and camel stocking rates. With a given cattle stocking rate, continually increasing camel stocking rates would inevitably force them into greater competition with cattle and impact on cattle productivity.

Camel production

When the breeding herd of camels was in Muller paddock, all classes of camels except calves lost weight between March and June 1998. This coincided with when the bull was in rut and included all of the pre-pubescent males that were one year old or less.

The bull camel's weight fell throughout the cooler months between March and June and again between June and September, coinciding with when he was showing obvious signs of rut. He then recovered to close to his March weight by November 1998. He showed no obvious signs of rut in March 1999, however his weight had fallen again. The measured cow weight losses may have been exaggerated, as several dry (non-lactating) camel cows were not trapped in the cooler weather. By September the cows weighed in June had regained to their March weights and they remained relatively constant afterwards, indicating that they had lost weight due to the bull being in rut. Had the cows been losing weight because of lactation, they would have been expected to continue to lose weight, because no calves were weaned during this period. By September, the 1996 born male camel weights exceeded their March weights. The 1997 born camel calf weights rose continually throughout the year.

Young bull camels were cograzed with steers in Muller paddock from March 1999. They gained an average of 122 kg in the 10 months between March 1999 and January 2000. The heaviest young bull weighed 470 kg in May 1999 and by the end of August he had come into rut and lost weight slightly. Presumably he came into rut because of the cow that had to be left in the paddock (had she not been there, he would not have been expected to come into rut). In April 2000 the young bull camels were transported to Alice Springs to form part of a proposed live export shipment to Malaysia. Several were showing signs of rut. They were weighed and had their collars removed after arriving in Alice Springs. Three days later they were re-weighed, as it was believed that the first weights could not have possibly been correct. The average weight loss between January and April was 58 kg, almost half of the weight gained in the 10 months prior to January. This loss was undoubtedly partially attributable to the difficulty of loading them using a portable ramp and then being transported. They had been loaded and unloaded on the same ramp before, but had grown in the meantime. The camels were re-weighed during 2000 as the live shipment was delayed. It took until late September for these camels to return to their January weights.

There was no evidence of rut in the young bulls in 2001. They gained an average of 109 kg each and their average final weight was over 500 kg, so several of them would certainly have been capable of coming into rut. The preceding eight months had been an extended extremely wet period, and such conditions are probably not ideal for camels in terms of maximising their productivity.

In contrast to the continual increase in steer weights, all of the classes of camels except for the calves lost weight when a single bull or several young bulls were in rut. Rutting behaviour in individual camels impacts greatly on the weight gain performance of the rutting animal. More importantly from a production point of view, all other camels except calves associated with the rutting bull also seem to be affected. To optimise growth rates of young male camels it seems necessary to remove them from breeding herds to prevent them from having contact with rutting bulls. To optimise growth rates of sub-adult males approaching sexual maturity, it also seems necessary to prevent them from having any contact whatsoever with sexually mature female camels, or, alternatively, castrate or neuter them by some other means. This is likely prove to be a significant production issue with camels because overseas demand for live camels is likely to be from Muslim countries that prefer entire animals, regardless of species, for religious reasons. It is extremely important that rutting activity in camels did not appear to impact on steer weight gains.

There appears to be significant scope for selection on production traits in camels such as growth rate, that are important in cattle and other meat producing species. Growth rates of the final group of young bull camels were unaffected by rutting behaviour and still varied considerably. Average daily gains in these young bulls ranged from less than 300 g/day to almost 750 g/day. Although there may easily have been undetected factors (illness or injury for example) contributing to the lowest average daily weight gain, there nevertheless appears to be quite a range in performance in terms of growth rate.

Camels are reported to have high salt requirements in international literature (eg. Akkada, 1986) and have been observed to regularly eat crystalline salt in Central Australia after drinking saline bore water with total dissolved solids of 10,000 ppm (Dorges and Heucke, 1995). Camels use salt to increase the efficiency of water and urea cycling (Yagil, 1996). The breeding herd of camels in Muller paddock were offered free access to salt at the water point but showed limited interest and although not measured, consumption was very low and the practice was discontinued.

Total livestock productivity
Livestock productivity from both paddocks was recorded in terms of maintenance and production per square kilometre. Direct productivity comparisons between paddocks are not possible because of the land type and stocking rate differences described. Productivity can not be compared between years

either for several reasons including different rainfall and seasonal conditions, using a breeder herd of camels then young bulls in different years and different initial steer weights each year.

To tease productivity differences due to paddock differences from those due to cograzing would require replication using the two grazing regimes in a number of different paddocks. However, to conduct such a project at a practical paddock scale in an arid environment would require considerable resources.

Running young bull camels as extra livestock, at a stocking rate of approximately one camel per square kilometre, increased total livestock productivity in terms of kilograms per square kilometre by 10% and 16% from cograzed paddocks in 1999/2000 and 2000/2001. As discussed in the previous section, the camels lost weight at the end of their time in the paddock in 1999/2000, coinciding with rutting behaviour. Consequently, their contribution to total livestock productivity was reduced.

The proportional contribution that camels could make to total livestock productivity in a cograzed area would be expected to be higher on land types that are marginal for cattle production. The same would be expected in areas with long distances between permanent water points (upwards of 15 to 20 kilometres). Such distances prevent cattle from normally accessing significant areas of pasture but pose little problem for camels.

This component of the project met project objective 1, by obtaining objective animal production data from cograzing compared to cattle grazing only. Objective 5 was not completely met. The project demonstrated that running camels as extra livestock improves livestock productivity. The project also demonstrated potential for increased income (if camel markets are consolidated and further expand) but did not clearly demonstrate potential for improved income stability. This objective was established with the idea that camels may provide a source of income during prolonged drought after cattle herds had been sold down and in the recovery phase after drought, when beef producers generally have reduced income during herd rebuilding. Longer term studies would be necessary to demonstrate potential for improved income stability from cograzing.

6. Implications

This project obtained objective vegetation utilisation and animal production information on cograzing cattle and camels in Central Australia. It was recognised at the outset of the project that four years could not cover the full gamut of seasonal conditions that can be experienced in Central Australia and the results reported here acknowledge this limitation. Nevertheless, results from this project indicate that successful outcome of unchanged cattle production alongside additional camel production can be achieved without negatively impacting on the pasture resource.

Cograzing will become more attractive to beef producers if camel markets continue to expand. Several recommendations are made and some issues that warrant further investigation if cograzing becomes more widely adopted have been identified. These recommendation and issues are presented in the following section.

Information from this project is relevant to an estimated 60% of the 250,000 square kilometres of pastoral land and 50,000 square kilometres of Aboriginal Pastoral Land south of 20°S in the NT. Information from this project is also relevant to large areas of arid and semi-arid Queensland, New South Wales, South Australia and Western Australia because of they have many common natural and man-made attributes.

As camel markets become better established, market signals should become clearer. At the time of writing it would be premature to provide a statement of costs and benefits of cograzing in production terms. Information from many sources, including this project, would be required to conduct a thorough cost-benefit analysis on cograzing. Such an analysis would need to recognise, for example, that there are situations where cograzing camels with cattle has definite advantages for weed control.

7. Recommendations

Recommendations that can be used by industry

The value of this project will depend on the consolidation of recent camel market expansions and further market growth. If this occurs, more beef producers will be attracted to cograzing and the following recommendations derived from the project can be used by industry.

Vegetation impact and dietary overlap
Compared to grazing cattle only, cograzing did not impact on grass utilisation or ground cover in terms of plant litter in a range of seasonal conditions. Forbs were more heavily utilised under cograzing. This did not translate into less pasture production during the project, but may do in the longer term. Many prickly forb species that cattle tend not to eat are highly palatable to camels. Similarly, many forbs that cattle tend to only eat when they are young and succulent before their prickles toughen, are also highly palatable to camels at all stages of growth. Although camels are perceived as browsing animals, they preferentially graze forbs if they are available. Camels rely heavily on trees and shrubs in dry times.

Several tree and shrub species are heavily utilised under cograzing. Many of the taller trees and shrubs that are palatable to cattle are browsed beyond their reach. Other tree and shrub species that are less palatable to cattle are also heavily utilised by camels. In particular, thorny and prickly species are heavily utilised by camels. The camels' prehensile upper lip and upper incisor teeth make them far better adapted to browsing such species than cattle. Tree and shrub species unpalatable to camels are also unpalatable to cattle.

Landholders have to accept that camels will always put heavy pressure on plant species such as plumbush and supplejack. With most highly affected plant species, spelling or some form of rotational grazing may be sufficient to protect them in paddocks where camels are kept. However, with plumbush (and a few other species in other areas) it is probably necessary to fence off stands to prevent their destruction.

Although cattle and camels have quite different dietary preferences camels will compete with cattle for certain species. Competition will primarily occur for forb, tree and shrub species that are palatable to both cattle and camels. Competition for grass is secondary and restricted to short periods after rain following dry periods when grasses respond more quickly than forbs. At these times camels will preferentially utilise fresh grass growth until forbs become available.

Cattle and camel production and management
Although the project did not use paddocks that were uniform in terms of land types, the results indicated that there was no change in steer liveweights as a result of cograzing. The results showed that any negative impact on steer weight gains that could possibly be attributed to cograzing was very minor. These result needs to be interpreted in light of the above points about competition for plant species between cattle and camels. Under a given set of seasonal and pasture conditions, continually increasing camel stocking rates would obviously force them into greater competition with cattle.

The results confirmed the expectation that running camels as extra livestock produced extra liveweight from the same area of land. The proportional contribution that camels could make to total livestock production would be expected to be higher on country that is more marginal for cattle and in areas where long distances between permanent water points deny cattle constant access to potential pasture.

Rutting behaviour markedly restricts camel productivity. Liveweight losses occurred in all classes of camels except calves, whenever a bull or bulls were in rut. Adult rutting bulls chase pre-pubescent yearling bulls away from their mothers and these young bulls lose weight. The net effect on their growth rates is unknown, but unless they exhibit full compensatory gain their overall growth rate would be slowed. All young male weaners should be removed to keep the herd calm, otherwise the dominant bull will always try to chase them away. Segregating sub-adult bulls from any contact with mature females appears essential to improve their productivity in terms of liveweight gain. Young bulls appear to come into rut at around 470 to 520 kg. When some members of a young bull group come into rut, weight gains of the entire group seem affected.

A sex ratio of one bull camel to 20-30 cows is recommended. Under conditions in the wild, one bull camel herds seven adult cows on average (1-24 cows; based on 517 sightings). With this sex ratio each bull camel will herd at least some cows during the breeding season and therefore minimise competition between males. Low bull percentages also minimise the probability of infanticide. In small paddocks it is important to keep only one bull regardless of the number of females. As camels are very mobile, too many encounters will occur with more than one bull in a small area. This will eventually lead to fights or at least to unnecessary turmoil and disturbance. Young females should remain with breeding groups to learn the skills of raising calves. In the wild young females regularly join mothers and small calves and stay with them.

No detrimental interactions between cattle and camels were observed in paddock or yard situations. Rutting behaviour in camels did not affect steer liveweight gains. Obviously, cattle and camels held together in the same yard need enough room to separate themselves.

Camels are reputedly very susceptible to urea poisoning. Providing supplementary Uramol® blocks that contain 30% urea for cattle caused no problem in this area and this is consistent with producer experience elsewhere in the Alice Springs district. Experience also shows that providing supplementary urea at rates safe for cattle in trough water using water medication units causes no problems for camels. Normal supplementary mineral feeding practices for cattle can be continued if cograzing.

In years with average rainfall a density of up to one or possibly 1.5 camels per km² seems appropriate for the paddocks investigated. This should apply relatively broadly to timbered (woodland) country that is among the more productive country for cattle in Central Australia. In high rainfall years with good seasons camel stocking rates can be increased, but should be reduced in dry years, as is practiced with other stock.

Dissemination of information arising from this project

Information from this project and other sources should be summarised in the form of Agnotes or Fact Sheets to provide information in a condensed form. Such publications could also include producer experiences.

The results of this project should form part of selected future pastoral or camel industry field days and seminars. This would be appropriate in the near future, when the recent expansion in live export camel markets have been consolidated. This would enable better information on supply and demand for camels and the financial implications of cograzing to be presented, along with the biological information derived from this and other projects.

Follow up activities

If the practice of cograzing becomes more widely adopted there are a number of management, production and vegetation impact issues that can be further investigated. Foremost among camel production issues identified is management to minimise, avoid or prevent the problems caused by rutting bull camels. The impact on pasture resources of grazing management regimes involving spelling and rotation of cattle and/or camels could be investigated, but require large resource commitments.

8. Appendices

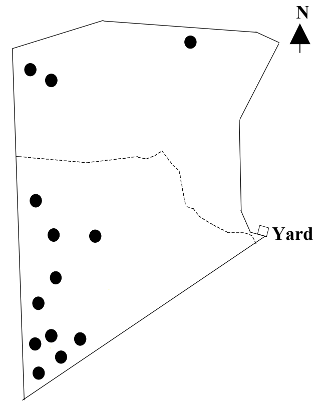
Appendix 1. Steer stocking rate calculations

LAND TYPE	Area (km^2)	AE*/(km^2)	Area x AE	No. steers = (Area x AE)/0.6
DPI paddock				
gidyea groves	1.7	1	1.70	2.8
small rocky hills/stony platforms	1.12	1	1.12	1.9
open shrubby mulga and woodland	3.63	2.5	9.08	15.1
mid-density shrubby mulga	2.34	1.5	3.51	5.9
open gravelly slopes/grassy flats	9.3	2.5	23.25	38.8
open sandy rise/woollybutt*	1.41	1.5	2.12	3.5
small closed drainage	0.38	4	1.52	2.5
mixed woodland minor drainage	0.32	3.5	1.12	1.9
dense mulga creekline	0.47	3	1.41	2.4
eucalypt sandy creekline	0.25	3	0.75	1.3
TOTAL	**20.91**		**45.6**	**76.1**
Average (AE or steers)/km^2			**2.18**	**3.6**
Muller paddock				
gidyea groves	0.56	1	0.56	0.9
small rocky hills/stony platforms	0.01	1.5	0.02	0.0
open shrubby mulga and woodland	5.95	2.5	14.88	24.8
open sandy rise/woollybutt**	0.95	2.5	2.38	4.0
mixed woodland minor drainage	0.93	3.5	3.26	5.4
TOTAL	**8.39**		**21.1**	**35.1**
Average (AE or steers)/km^2			**2.51**	**4.2**
** better country in Muller paddock as there's much less spinifex				

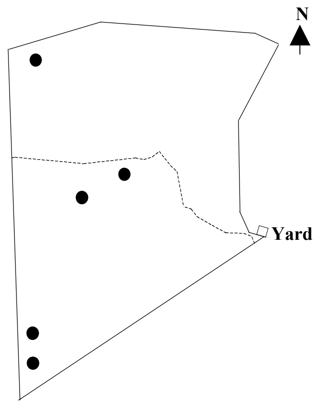
*Animal Equivalent growing stock (source 1982 NRC)

Appendix 2. Range utilisation by camels in cograzed paddocks June 1996 to April 2001.

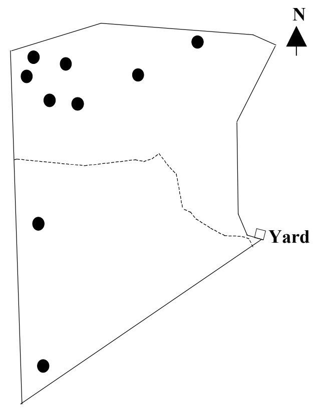
June 1996



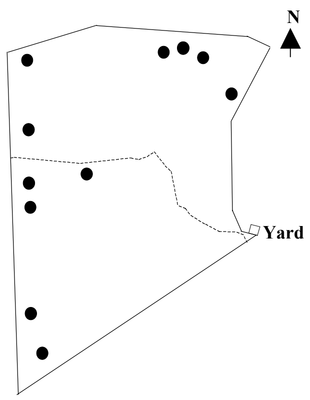
July 1996



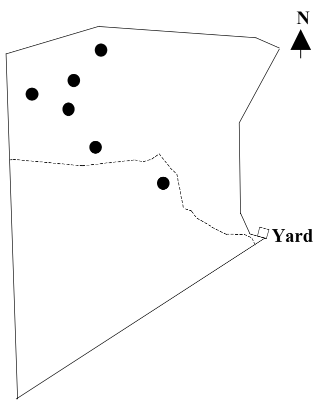
August 1996



November 1996



March 1997



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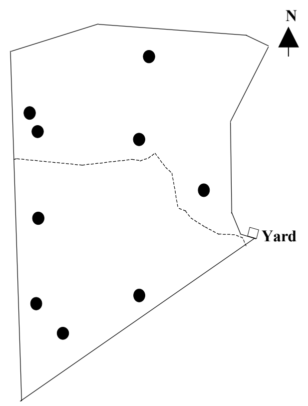
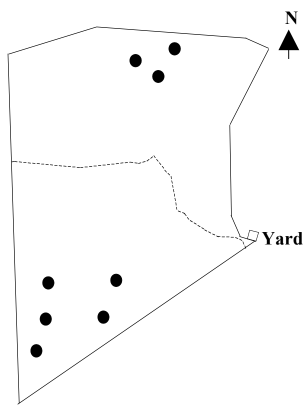


December 1997



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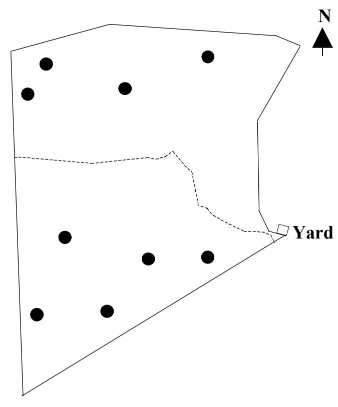

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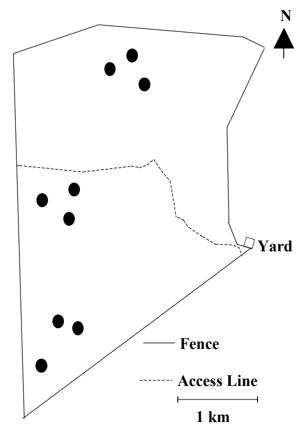
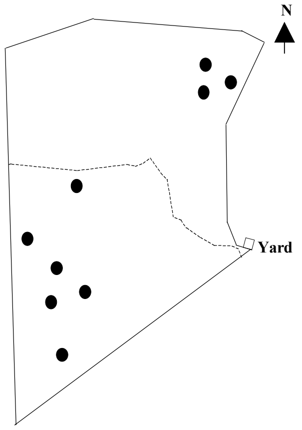


Appendix 2 cont.

September 1998



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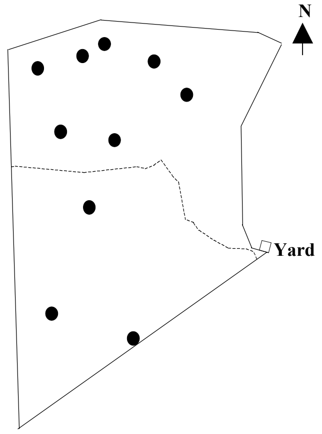

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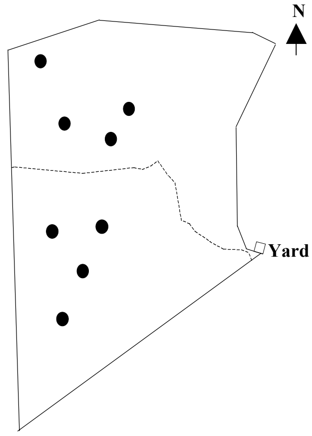

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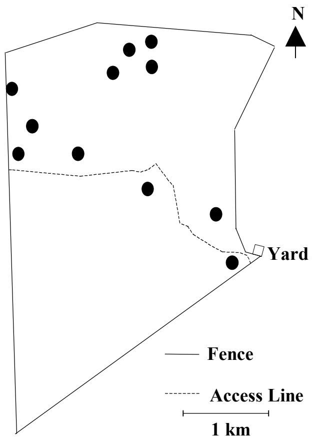

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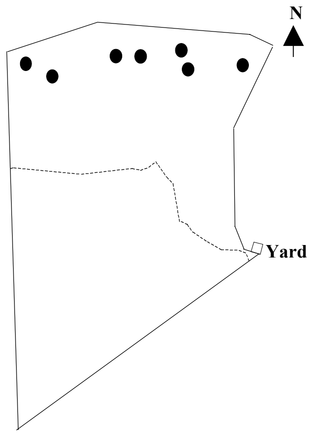

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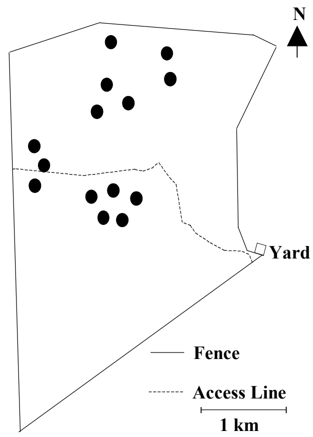

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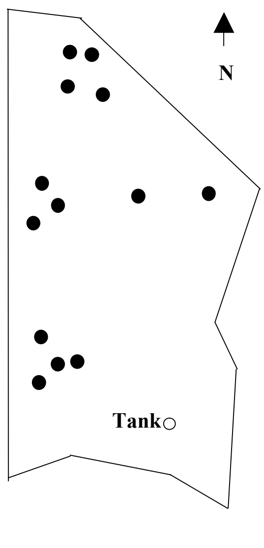

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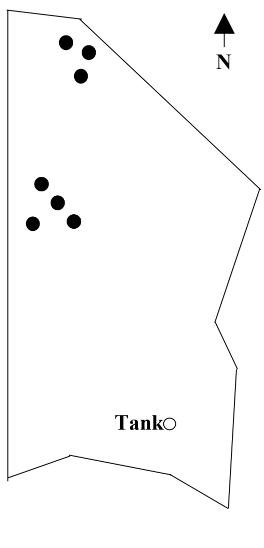
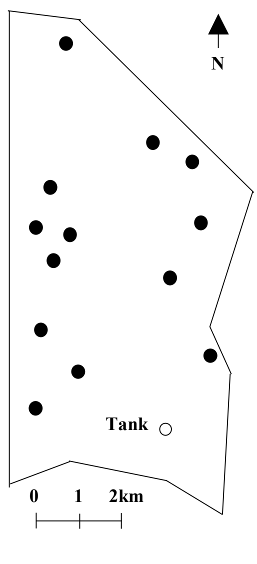
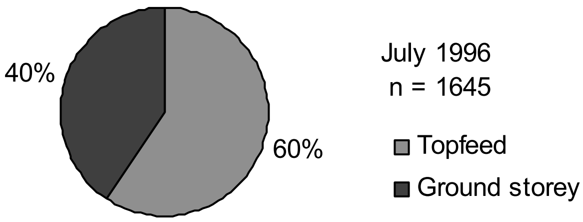
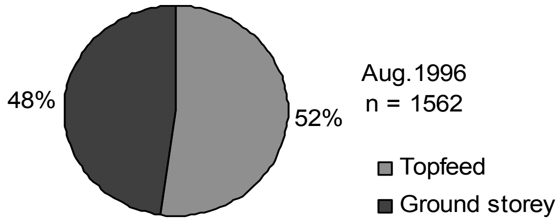


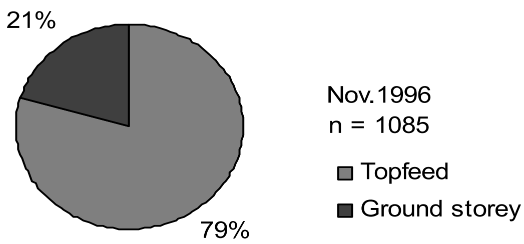
April 2001

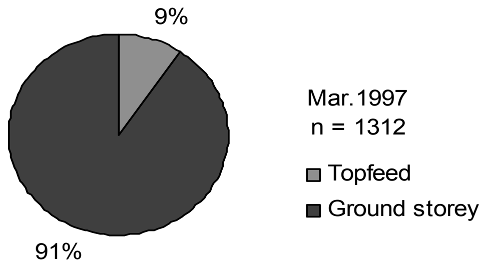


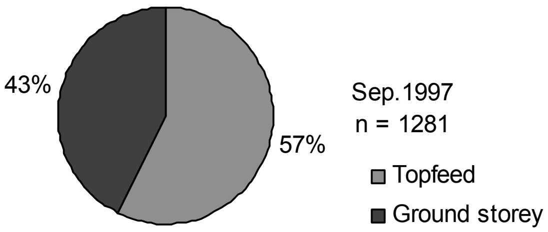
Appendix 3. Proportion of dietary topfeed and ground storey species July 1996 to April 2001.

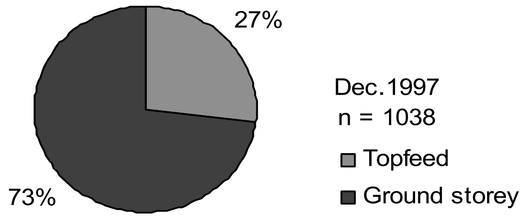


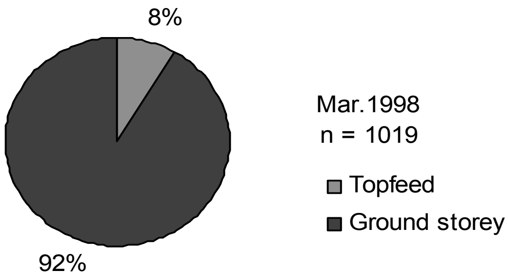


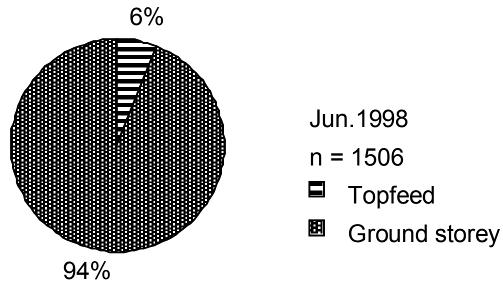


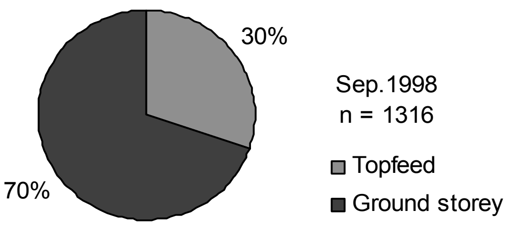


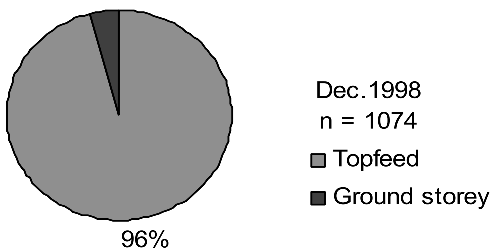




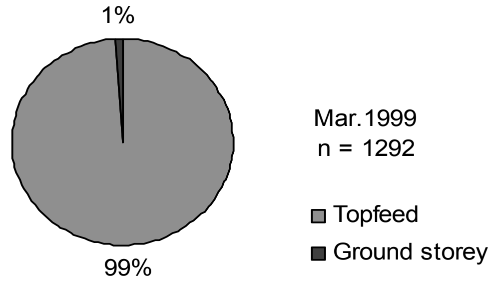


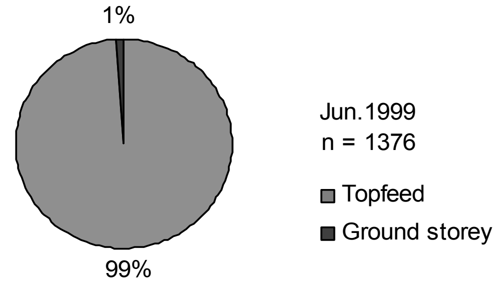


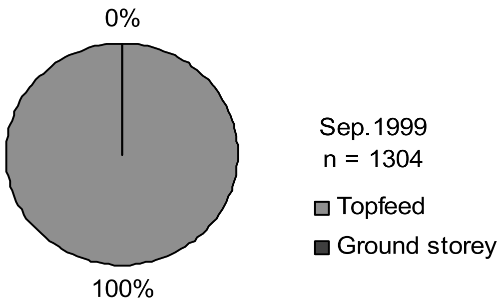


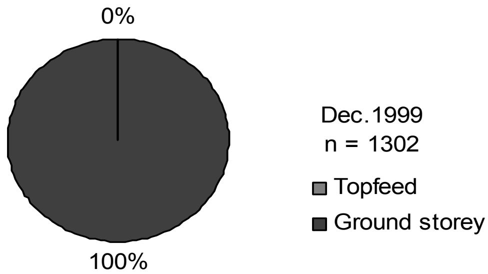


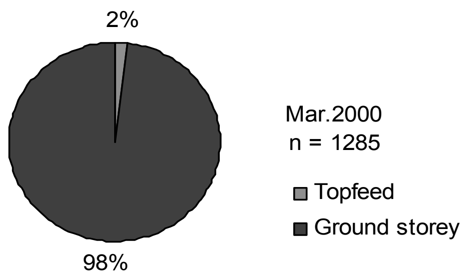
Appendix 3 cont.

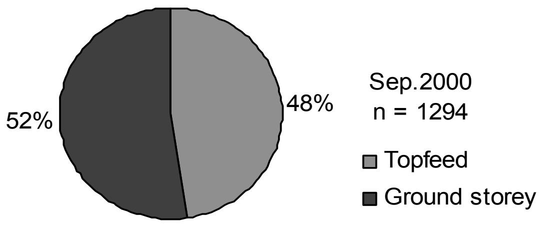


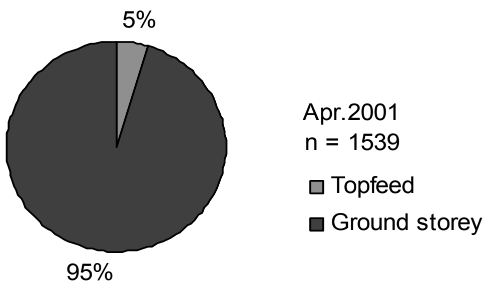












Appendix 4. Results of quantitative food analyses for camels in Muller paddock, July 1996 – March 1998.

Topfeed	**Jul-96**	**Aug-96**	**Nov-96**	**Mar-97**	**Sep-97**	**Dec-97**	**Mar-98**
Acacia aneura		117		6		32	
Acacia estrophiolata		88	166	12	177	86	35
Acacia farnesiana	75						
Acacia georginae					161		
Acacia kempeana					157		20
Acacia ligulata	57	75	67		69		
Acacia murrayana			99	17			
Acacia victoriae	217	67	57		49	50	
Atalaya hemiglauca	368	275	173	36	94	51	
Corymbia aparrerinja							
Corymbia opaca						43	
Eremophila longifolia							
Grevillea striata			151			4	12
Hakea divaricata			28			9	
Hakea subera			34			13	19
Rhagodia eremaea	91		49		27		
Ventilago viminalis	172	195	38	52			
Ground storey							
Herbs & small shrubs							
Abutilon species		30			53		37
Atriplex species			36				
Boerhavia species	217	180		417	78	51	524
Chenopodium mel.		71					
Enchylaena tomentosa			31	12	27		
Evolvulus alsinoides	37		57		77		
Indigofera species						20	
Lepidium species					116		
Portulaca species	18	31				36	72
Salsola kali	67	81	44	49	43		
Sclerolaena species	255	179	28	25			
Tribulus species	45	138		529	81	63	188
Grasses				71		213	
Dactyloctenium rad.						19	95
Enneapogon species						120	
Fimbristylis species						120	
Plectrachne species				55			
unidentified	26	35	27	31	72	108	17
No. observed	**1645**	**1562**	**1085**	**1312**	**1281**	**1038**	**1019**

Appendix 5. Results of quantitative food analyses for camels in Muller paddock, June 1998 – March 2000.

	Jun-98	**Sep-98**	**Dec-98**	**Mar-99**	**Jun-99**	**Sep-99**	**Dec-99**	**Mar-00**
Topfeed								
Acacia aneura	10	62	175	144	108	598	6	
Acacia estrophiolata	45	108	328	493	461	375		
Acacia farnesiana								
Acacia georginae		66	211	261	581		10	
Acacia kempeana		35	88	121				
Acacia ligulata			25			67		
Acacia murrayana						104		
Acacia tetragonophylla	32							
Acacia victoriae								
Atalaya hemiglauca		24		112	109	41	7	
Corymbia aparrerinja			57	89				
Corymbia opaca			48			88		
Eremophila longifolia								
Grevillea striata		45	31	57	77			
Hakea divaricata					26			
Hakea subera			30					
Rhagodia eremaea		21				31	2	
Ventilago viminalis		37						
Ground storey								
Herbs & small shrubs								
Abutilon species	27	49	26	15				
Atriplex species								
Boerhavia species	279	157					499	
Chenopodium mel.								
Cleome viscosa								28
Enchylaena tomentosa								
Evolvulus alsinoides		77						
Helichrysum species		98						
Indigofera species	471	264						
Lepidium species								
Portulaca species		23						63
Salsola kali	24	16					75	1075
Sclerolaena species		24						51
Tribulus species	316	182					618	
Grasses	271		14					26
Dactyloctenium rad.							87	
Enneapogon species								
Fimbristylis species								
Plectrachne species								
unidentified	31	28	5		14		23	17
No. observed	**1506**	**1316**	**1038**	**1292**	**1376**	**1304**	**1302**	**1285**

Appendix 6. Results of quantitative food analyses for camels in DPI paddock

Topfeed	**Sep-00**	**Apr-01**
Acacia aneura	76	
Acacia kempeana	35	
Acacia ligulata	59	
Acacia victoriae		12
Amyema maidenii	3	
Atalaya hemiglauca	89	23
Corymbia opaca	29	
Eremophila longifolia	24	
Grevillea striata	48	
Jasmidum didyn.	79	
Rhagodia eremaea	51	8
Santalum lanceolatum	27	19
Ventilago viminalis		9
Ground storey		
Herbs & small shrubs		
Anthobolus lept.	17	
Boerhavia species		401
Calandrinia species	89	
Calotis latiuscula	20	17
Enchylaena tomentosa	34	
Glycine falcata	28	
Lepidium species	61	
Portulaca species	99	
Pterocaulon sphacel.		375
Salsola kali	256	359
Scaevola species	33	
Sclerolaena species	28	86
Stenopetalum nutans	54	109
Tribulus species		121
Trichodesma zeylan.	11	
Grasses		
Plectrachne species	24	
Unidentified	20	
No. observed	**1294**	**1539**

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