late March will provide one heavy or two light early grazings and should compensate for any loss of production later in the season. Early-sown ryegrass has only a slight chance of being more affected by rust than later-sown swards, even with the more susceptible cultivars such as Wimmera and Grasslands Tama (Lowe *et al.* 1984).

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SELECTION OF PLANT SPECIES BY CATTLE GRAZING NATIVE MONSOON TALLGRASS PASTURE AT KATHERINE, N.T.

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ABSTRACT

The defoliation of pasture species by cattle was monitored for two wet-dry seasonal cycles in recently burnt native monsoon perennial tallgrass pastures. Three uncleared 50 ha paddocks were used. Alternate halves of each paddock were burnt each dry season. Relative defoliation ratings were combined with relative abundance (frequency of occurrence) values to derive, for each pasture species, a selectivity index, whose values could range from —*1 to +1, with zero indicating non-selective grazing.*

The mean index values for the four dominant perennial grass species Themeda triandra *(formerly* T. australis*),* Sehima nervosum, Sorghum plumosum *and* Chrysopogon fallax*) were significantly different (respectively 0.49, 0.14, 0.04 and* —*0.44) and indicated selectivity for* Themeda *and avoidance of* Chrysopogon. *The cattle were least selective at the start of the rainy season when the post-burn growth was short, and were most selective at the end of the rainy season when herbage was stemmy and mature.*

*Four other pasture components (*Eriachne obtusa, *annual grasses, leguminous forbs and other forbs) were generally rejected by the cattle.*

The approach described forms the basis of a rapid field survey technique for assessing diet selection.

INTRODUCTION

The native rangelands of the wet-dry tropics of northern Australia are savannas, many of which are almost entirely composed of rapidly-growing, rank, perennial grass species of poor nutritive value (Mott *et al.* 1986). In these pastures cattle prefer to graze the short, young growth which occurs in recently burnt areas (Andrew 1986), or in patches previously grazed. The rest of the pasture is largely ignored resulting in a mosaic of heavily grazed and rank, ungrazed plants. It might be expected, therefore, that cattle do not graze these native species selectively, the attractiveness of the new, accessible growth in the patches overriding any differences in preference for the species. If so, this would be in marked contrast with the archetypal rangeland situation in which pastures comprise a mix of forage species of different types (shrubs, forbs and grasses; annuals and perennials) of widely varying palatabilities. In such pastures, selective grazing, acting with other processes, favours some species (the increasers) over others (decreasers) (Wilson and Harrington 1984). Because of this, dietary selection is viewed as a key process in rangeland science.

Survey data on defoliation of individual pasture plants (Andrew 1986) were available to examine the hypothesis, apparently for the first time, that selectivity between pasture species is minimal in perennial monsoon tallgrass pasture. This paper reports the results. The approach I use forms the basis of a useful method for examining diet selection by field survey.

This work comprises part of a program designed to give a better understanding of the ecology and management of the tropical native pastures of north-west Australia.

METHODS

Study site

This study was conducted at the Manbulloo research site, 50 km SW of Katherine, Australia (14°47′S, 131°57′E). Katherine has a mean annual rainfall of 950 mm which falls mainly in the summer months of December to March. The natural vegetation is monsoon tallgrass savanna (Mott *et al.* 1986) comprising a low open eucalypt woodland with a tall (1–2 m) perennial grass understorey dominated by *Themeda triandra (*formerly *T. australis*), *Chrysopogon fallax*, *Sehima nervosum* and *Sorghum plumosum* (Mott and McDonald 1981). Total dry matter production of all pasture species is about 2.5 t ha^{-1} $year^{-1}$ (Andrew 1986).

Field procedure

The data were gathered during a study of the influence of dry season burning on the spatial distribution of cattle grazing (Andrew 1986). Three uncleared native pasture paddocks, each of *c.* 50 ha, were bisected by a central firebreak, and each half was burnt biennially in July in an annual rotation. Each paddock was set-stocked with four steers (two pairs of 3/4–7/8 Brahman × shorthorn, with the oldest pair replaced each year with 18 month old animals). The cattle were fed a complete mineral supplement as blocks (ICI Ultrapro 50®). The mean botanical composition of the burnt halves of the three paddocks is given in Table 1.

The paddocks were surveyed at approximately monthly intervals, from December 1983 to June 1985, to assess the degree to which various pasture species (or species groups) had been grazed. Permanent transects, 600 m long and *c.* 60 m apart, were laid out across the paddocks, and quadrats of 1 m^2 were sampled at 40 m intervals along the transects. There were at least 65 quadrats in each half-paddock. The pasture species present in each quadrat were recorded, and the degree to which each species had been defoliated up to the time of each survey was estimated according to the scale: 0 = no grazing; 1 = a trace ($<$ 5% of the growth removed); 2 = $>$ 5% and $<$ 25%; 3 = $>$ 25% and $<$ 50%; 4 = $>$ 50% and $<$ 75%; and 5 = $>$ 75%. This approach is similar to that used by Pechanec and Pickford (1937), Kruger and Edwards (1972), and Grunow and Rabie (1978). Exclosures were erected throughout the paddocks in August 1984 to provide a reference of ungrazed plants.

Data analysis

The analysis was restricted to observations made in the most recently burnt half of each paddock, because this is where the cattle concentrated their grazing (Andrew 1986). The inclusion of the data for the rank, unburnt pasture, which was largely ignored by the cattle, would have given a spurious assessment of diet selectivity.

To construct a selectivity index requires a measure of both dietary consumption and abundance in the pasture of each pasture species. For consumption I used the defoliation rating. For abundance I used frequency of occurrence, following the approach of de Leeuw (1979), since this is obtained directly from the defoliation survey data. Each defoliation rating was converted to the mean value of the corresponding percentage range (e.g. 37.5% defoliation for rating = 3), and summed for each species for each paddock, along with the number of quadrats in which each species occurred. These values were compared with the grand totals over all species for each paddock and time using a selectivity index:

$$S.I._i = (RelCONS_i - RelABUND_i)/(RelCONS_i + RelABUND_i)$$

where:

$S.I._i$ = Selectivity Index for species i

$RelCONS_i$ = Relative Consumption of species i = (total % defoliation of species i)/(Grand total % defoliation for all species)

$RelABUND_i$ = Relative Abundance of species i = (occurrence of species i)/(occurrence of all species).

This index (based on the "electivity" index of Ivlev 1961) has the advantage of being bounded between −1 and +1, with 0 indicating no selection (i.e. a species is consumed in equal proportion to its abundance). By contrast, the commonly used "selection ratio" ($RelCONS_i$ /$RelABUND_i$, Hodgson 1979) is positively skewed with no upper bound, which makes it less useful for statistical comparisons.

Indices derived from less than 10 occurrences of a species in a half-paddock were excluded from the analysis on the grounds that they would be subject to too much random error. This left only the four major perennial grass species (*S. plumosum*, *T. triandra*, *C. fallax* and *S. nervosum*) well represented in the dataset. These data were subjected to an Analysis of Variance, and trends over time were examined using orthogonal polynomial contrasts up to order 4. Excluded values were estimated. These comprised 4, 15, 3 and 1 of the 48 data values of each of *S. plumosum*, *T. triandra*, *C. fallax* and *S. nervosum*, respectively. The large number of missing values for *T. triandra* is due mostly to one paddock in which it was not abundant. Data transformation was unnecessary, as judged from the distribution of the residual values.

To compare other species with the four perennial grasses, the mean selection indices of all species were calculated using all non-missing and non-excluded data for the March-May periods for 1984 and 1985, being the end of the rainy season when cattle grazed the dominant grasses most selectively (see below). T-tests were used to test whether these means were significantly different from zero. Calculations were made using GENSTAT Version 4.04.

RESULTS

The four dominant perennial grasses

Two main points emerged from the analysis. First, the mean Selectivity Index values over time were significantly different between the species ($P < 0.001$). *T. triandra* was the most selected (mean S.I. = 0.49), *S. nervosum* and *S. plumosum* were neither selected nor rejected (mean S.I. = 0.14 and 0.04 respectively), while *C. fallax* was generally rejected (mean S.I. = −0.44). Second, the relative degree of selectivity for these species changed over time in a periodic manner ($P < 0.001$) (Fig. 1). The cattle grazed least selectively at the start of the rainy season (November-December 1983) when the post-burn pasture was fresh and short. However the S.I.'s quickly diverged as the season progressed and the grasses became more rank. The difference between the S.I.'s of the most preferred species (*T. triandra*) and the least preferred (*C. fallax*) increased to a maximum towards the end of the rainy season (March–April 1984) and decreased as the dry season progressed. This pattern was repeated during the second year (1984–5) on the other paddock-halves which were burnt in July 1984. This periodic annual pattern of diet selectivity was reflected in a significant interaction between species and date of sampling ($P < 0.001$), which was comprised of linear ($P = 0.003$), cubic ($P < 0.001$) and quartic ($P < 0.001$) trends in the values of S.I. over time. The trends were different among the species. The linear trend was evident also in the mean values over all four species: mean S.I. fell by 0.16 units year^{-1} ($P < 0.001$). *S. nervosum* showed the greatest decline in S.I. (—0.42 S.I. year^{-1}), and only for *T. triandra* was there a positive trend (0.04 S.I. year^{-1}). I have no explanation for these linear trends in S.I. values. The cubic and quartic trends are consistent with an annual pattern in dietary selection which is basically periodic. For example, the S.I. of *S. plumosum* fell in February–March of each year which corresponded with the shedding of its spear-like, awned seeds from the tall (> 2 m) culms, and rose again shortly after when it was still producing fresh growth (Fig. 1). The periodic trends were displaced among the species (hence the significant interactions) indicating that the cattle tended to switch between the species as time progressed.

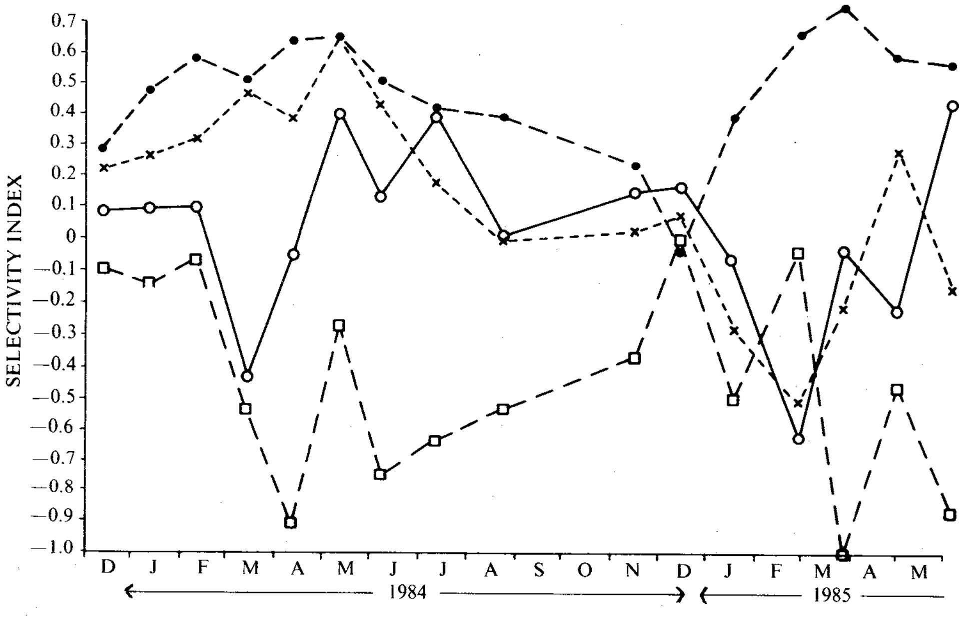

FIGURE 1

The mean values of the Selection Index for four native tropical grass species, obtained from analysis of Variance (see text): o, *Sorghum plumosum*; •, *Themeda triandra*; □, *Chrysopogon fallax*; x, *Sehima nervosum*.

All pasture species

The magnitude and sign of the mean S.I. values for the four perennial species at the end of the two rainy seasons (Table 1) correspond well with those of the mean values obtained from the analysis of all the data (given above). The other four pasture components (the stemmy perennial grass *Eriachne obtusa*, annual grasses, native legume forbs, and non-legume forbs) were significantly avoided (S.I. $< < 0$) during this period. The S.I. values for these species calculated at other sampling times were also negative.

TABLE 1

The mean percentage composition of the pasture by weight in April for 1984 and 1985; and the values of the Selection Indices for all species meaned over the two years for the March-May period when cattle grazed most selectively

Species	Composition by weight	Mean Selection Index	Standard deviation	Probability[1]
	(%)			
Sorghum plumosum	25	—0.16(17)[2]	0.53	NS
Themeda triandra	15	0.65(13)	0.11	***
Chrysopogon fallax	20	—0.53(18)	0.45	***
Sehima nervosum	29	0.18(18)	0.53	NS
Eriachne obtusa	3	—0.84(16)	0.35	***
Annual grasses[3]	1	—0.79(16)	0.40	***
Native leguminous forbs[4]	2	—0.95(18)	0.15	***
Non-legume forbs	2	—0.98(18)	0.07	***

[1] Probability that mean S.I. is different from zero; NS, non-significant; ***, $P < 0.001$

[2] Number of observations contributing to the mean.

[3] Mainly *Aristida browniana, Brachyachne convergens, Digitaria gibbosa, Eriachne ciliata, Perotis rara, Rottboellia formosa* and *Sporobolus* sp.

[4] Mainly *Alysicarpus rugosus, Cassia mimusoides, Crotalaria linifolia, C. medicagenea, Galactia* sp., *Indigofera linifolia, I. colutea, I. parviflora, Rhyncosia minima, Tephrosia remotiflora, Uraria cylindrica, Vigna lanceolata, V. radiata* var. *sublobata* and *Zornia diphylla*.

DISCUSSION

Cattle grazed the native perennial grass and other species at the Manbulloo research site selectively, but none of the four major pasture components was excluded from their diet. The degree to which this selectivity was expressed for the four main perennial grass species appeared to follow the pattern of phenological development of the pasture; selectivity was least when the pasture was fresh and short, which is when it is also most nutritious (Norman 1963). Duvall and Whitaker (1964) obtained similar results in rotationally-burnt sub-tropical Bluestem pasture in Louisiana.

It is important to remember that even in these burnt pastures, most of the material becomes rank and ungrazed by the end of the rainy season. Because the stocking rate is low (12 ha $beast^{-1}$), the total area grazed by the cattle at that time is small (about 10% of quadrats showed any evidence of grazing, including the quadrats near the water troughs). In the case of *T. triandra* and *S. plumosum* however, I observed that some of this rank material was eaten by the cattle during the dry season when they grazed some dry tops containing remains of seedheads, but this is not detectable in Fig. 1. Duvall and Whitaker (1964) reported similar behaviour by cattle. The S.I. values converged during the dry season, due to a decline in selectivity for *T. triandra* and *S. nervosum*—which do not produce any new growth during this period—and a rising selectivity (though still negative) for *C. fallax* and a slightly elevated selection for *S. plumosum*—the two species which do produce some fresh growth over the dry season (Arndt and Norman 1959; and *personal observation*).

The selection of *T. triandra* by cattle at Manbulloo accords with its status as a valuable pasture species throughout its extensive natural range in Australia. It is surprising that cattle did not show greater selection for *S. plumosum* in these paddocks since it is highly regarded by pastoralists as a pasture species in north-west Australia (Arndt and Norman 1959). This species was actively sought by cattle and quickly grazed out in other paddocks at Manbulloo. However, the circumstances under which this occurred were quite different: in the other paddocks *S. plumosum* was much less abundant initially (the norm for the region), the stocking rates were about 10-fold greater, the pastures were not burnt, and pasture legumes were oversown (J. J. Mott, *unpublished data*). In respect of the last three factors, the circumstances of the present study were close to normal station practice. The results for *C. fallax* accord with the comments of Arndt and Norman (1959) that it "... appears to be unpalatable to cattle at all times except in the first few weeks of growth".

The patterns in selectivity for the different species obtained at Katherine will need to be checked before being applied to other sites, because selectivity depends both on inherent palatability characteristics of the plants as well as relative species availabilities in the field (Hodgson 1979). Ecotypes of *T. triandra* and *C. fallax* from Townsville and central Queensland differ markedly in morphology—and hence, perhaps, palatability—when grown together with local strains at Katherine (J. J. Mott, M. H. Andrew, J. C. Tothill, J. G. McIvor and T. J. Hall, *unpublished data*). Furthermore, as well as the particular mix of species which occurred in the paddocks used in this study, these paddocks were unusually uniform in pasture composition. At the scale of a pastoral property, cattle would have access to a range of land units and pasture types. McNaughton (1978) provides a good example of how the selectivity of a particular species can be influenced by the other species growing in association with it.

Rejection of the annual grasses and the forbs (including the native legumes) by the cattle is noteworthy, because in many other situations this component is frequently the most selected (e.g. for sheep grazing in tropical, *Astrebla* spp. grassland of north-west Queensland, the S.I. of forbs averaged 0.75 [calculated from Table 4 of Lorimer 1978]). It is noteworthy that the improved pasture legumes, *Stylosanthes* spp., are also selected against at Manbulloo for much of the year when grown without superphosphate (McLean *et al.* 1981). The native pastures sampled here were unfertilized.

It would appear that diet selection is not a major factor in the management of these perennial monsoon tallgrass pastures, for two reasons. First, cattle grazed least selectively between the major pasture components (the four perennial grasses) at the start of the rainy season which is when the grasses are most sensitive to grazing (Mott 1986). Thus the differences in selectivity, between these grasses, which develop later in the season, probably have only a small influence on their relative survival and production. Mott (1986) reported that there was no difference in species composition between the newly-formed grazed patches and the surrounding pasture in the pasture types studied here, probably because the patches are formed at the time of least selective grazing. Second, these same grasses are long-lived and recruit only slowly (Mott *et al.* 1986). Thus, changes in botanical composition should occur only slowly in this pasture type, especially if grazed pasture is spelled before selective grazing determines grass survival (spelling occurs under the prevailing rotational burning regime, Andrew 1986). Indeed, there have been no marked changes in the botanical composition of these experimental paddocks over about 6 years (W. H. Winter and M. H. Andrew, *unpublished data*).

This study has shown that useful information on the spatial (Andrew 1986) and selective nature of grazing can be obtained by a simple extension of a routine pasture survey. The method is simpler than using fistulated animals and provides a more integrated estimate of the animals' diet over time. A difficulty of the method is obtaining calibration data. The defoliation data are necessarily estimates of cumulative utilization—it would be quite impractical in a rapid field technique to measure the extra defoliation which had occurred from the time of the previous survey. Because the tussocks in the grazed patches are defoliated from the very start of the rainy season, and because these grasses respond to defoliation in a number of ways including reduced growth in the remainder of the rainy season (Andrew 1986), calibration cannot be effected simply by clipping given proportions of dry matter from ungrazed plants at the time of each survey, as has been done in Mitchell grass pastures in which perennial grasses are defoliated relatively uniformly and mostly after growth has ceased (D. M. Orr, *personal communication*). Consistency between observers, and speed of training, was aided by using a coarse (6-point) scale (e.g. a regression of the defoliation estimates by the two major observers in this study on 57 samples was not significantly different from a 1:1 relationship, with r = 0.74). Nevertheless, the field procedure could be refined by maintaining a set of reference plants over the rainy season of known defoliation history, and using instant photographs for field reference on each sampling occasion. Another difficulty is in distinguishing, in rapid pasture surveys, between the defoliations of different species of herbivores, but this is not a serious problem when most of the grazing is due to the herbivore of interest, as in the present study. As with any rapid field method, care must be taken not to overlook minor pasture components in dense quadrats, or to mis-identify tussocks when stubble height is short. I suspect that any inconsistencies between observers were probably due more to these factors than to the estimation of defoliation scores *per se*.

The method I used is an elaboration of those of Kruger and Edwards (1972) and deLeeuw (1979). The former estimated percentage defoliation using a 4-point scale and calculated a relative consumption for each species, but did not combine this with relative abundance to derive a true selection index. DeLeeuw (1979) used a 2-point defoliation scale (grazed or not), from which he derived a standard "selection ratio" (relative frequency of defoliation/relative frequency of occurrence) as his preference index. As used here, my method does not utilize quadrat yield information when using the defoliation scores; i.e. a given percentage of defoliation has the same value whether the quadrat is high yielding or low yielding. The method could be further refined by estimating the percentage composition of each species in each quadrat directly (rather than use the dry-weight-rank method of 't Mannetje and Haydock (1963) to obtain only an average for the pasture). Used together with quadrat yield estimates, this would permit the defoliation scores and species abundances to be expressed on a dry weight basis for each quadrat, from which a more usual selection index based on weight could be constructed.

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EFFECT OF FERTILIZER AND WEED CONTROL ON THE EMERGENCE AND EARLY GROWTH OF FIVE LEGUMINOUS FODDER SHRUBS

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ABSTRACT

A field experiment was conducted at Mt Cotton, southeast Queensland, to examine the effects of nitrogen and phosphorus fertilizers and weed control on the emergence and early growth of five leguminous shrubs. Under good nutrition and no weed competition, the shoot dry matter yield at 11 weeks was 294, 239, 66, 25 and 21 g m^{-1} *of row for* Sesbania sesban, S. formosa, Leucaena leucocephala, Acacia angustissima *and* Calliandra calothrysus, *respectively.*

The taller, faster growing Sesbania *species were less susceptible to weed competition than the other three species, their yields being reduced by* c. 65% *as compared to* c. 80% *for the others. The application at sowing of N (100 kg N ha*$^{-1}$*) and P (200 kg P ha*$^{-1}$*) fertilizer in a band near the seed increased the growth of the two* Sesbania *species but depressed yields in the other 3 species. Weed yield increased with fertilizer application in the presence of* C. calothrysus *and* L. leucocephala *and was unaffected in the presence of the others. Fertilizer adversely affected seedling emergence and nodulation in all species.*

INTRODUCTION

Increasing interest is being shown in the use of leguminous trees and shrubs as sources of fodder for livestock in tropical and sub-tropical regions (NAS 1979). In comparison to herbaceous legumes, shrub species offer advantages in terms of superior persistence (Jones and Jones 1982), higher yields, resistance to mismanagement and the ability to retain high quality forage under conditions of stress.

However, if these species are to be widely accepted they must propagate easily, preferably by seed. At present, the most serious limitation to their widespread use is their slow and difficult establishment phase. Jones and Bray (1983) point out that leucaena which offers great potential as a fodder species has been poorly accepted in Australia mainly because of its slow establishment.

This study was conducted to compare the emergence and early growth of five shrub species (*Acacia angustissima, Calliandra calothrysus, Leucaena leucocephala* cv. Cunningham, *Sesbania formosa* and *S. sesban*) which have shown potential as fodder plants.

MATERIALS AND METHODS

The experiment was conducted at the University of Queensland Research Farm at Mt Cotton (27°35′S, 153°E) on an infertile grey podzolic soil with a sandy clay loam surface horizon of pH 5.2.

The area had previously been cropped with sorghum and oats and had received 200 kg ha^{-1} single superphosphate and 100 kg ha^{-1} muriate of potash annually for 3 years. Total nitrogen content of the surface soil was 0.11%, available phosphorus was 7 ppm (sodium bicarbonate extract) and organic carbon 1.3%.