Dynamics of plant populations in *Heteropogon contortus* (black speargrass) pastures on a granite landscape in southern Queensland. 3. Dynamics of *Aristida* spp. populations

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Abstract

The dynamics of the unpalatable *Aristida* spp. (wiregrasses) were measured in a subset of treatments contained within an extensive grazing study conducted between 1990 and 1996 in *H. contortus* pasture in southern Queensland. This paper reports the results from these treatments which included 2 land classes (silver-leaved and narrow-leaved ironbark), 3 stocking rates (0.3, 0.6 and 0.9 beasts/ha) in both native pasture and legume-oversown native pasture, all in the absence of fire.

Changes in plant density and basal area of *Aristida* spp. reflected differences in both the survival and size of existing plants together with a large seedling recruitment in 1991. Two different taxa of *Aristida* spp. were distinguished; however, there were no clear differences in the response of these 2 taxa to the treatments. Grazing had the greatest impact on population dynamics through reducing basal area as stocking rate increased. Neither landscape position nor legume oversowing had a major impact on *Aristida* spp.

The results suggest that populations of *Aristida* spp. will be highest under light grazing and that seedling recruitment may be episodic.

Introduction

Aristida spp. (wiregrasses) are a common component of many pasture communities in Queensland and are generally unpalatable to grazing animals. For example, *A. armata* (wiregrass) is common in *Acacia aneura* (mulga) pastures (Brown 1986), *A. leptopoda* (white speargrass) in *Dichanthium sericeum* (Queensland bluegrass) pastures (Bisset 1960; Jacobsen 1981), *A. ramosa* (purple wiregrass) in southern *Heteropogon contortus* (black speargrass) pastures (Paton and Rickert 1989) and *A. latifolia* (feathertop wiregrass) in *Astrebla* (Mitchell grass) pastures (Lee *et al*. 1980). Despite the widespread occurrence of *Aristida* spp., little is known of their population processes.

This paper reports the dynamics of *Aristida* spp. populations as affected by landscape position and stocking rate in both native (*H. contortus)* pasture and legume-oversown native pasture in southern Queensland between 1990 and 1996.

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Materials and methods

Site

A grazing study was conducted between December 1989–March 1996 in a *H. contortus* pasture on a granite-derived soil at "Glenwood" station, 50 km west of Mundubbera (25°41′S, 150°52′E). The overall study consisted of 4 land classes and 3 stocking rates on either native pasture or legume–oversown native pasture. This paper will focus on a subset of data including 2 land classes (narrow-leaved ironbark and silver-leaved ironbark), at 3 nominal stocking rates (0.3, 0.6 and 0.9 beasts/ha) in both native pasture and legume-oversown native pasture. There were 2 replicates of the 0.3 and 0.6 beasts/ha stocking rates for the native pasture and legume-oversown native pasture in both land classes. However, there was only 1 replicate of the 0.9 beasts/ha treatment in each of the 2 land classes and only for the legume-oversown native pasture. This grazing study was severely impacted by drought and further details are presented in Orr *et al*. (2004a).

Measurements

Details of the selection of permanent quadrats for the study of *H. contortus* are given in Orr *et al*. (2004a). Briefly, 20 permanent quadrats, each 0.5 × 0.5 m, were established in each treatment paddock in autumn 1990 in 2 nests each of 10 quadrats to contain a total of approximately 60 *H. contortus* plants representative of each paddock. This paper reports the population dynamics of the variable number of *Aristida* spp. plants that occurred within these 20 quadrats.

Commencing in autumn 1990, the position of individual *Aristida* spp. plants in each quadrat was charted using a pantograph (Williams 1970) and the diameter measured firstly along the widest diameter and secondly in the perpendicular direction to this widest diameter. All plants of *Aristida* spp. were classified as mature or seedling (<1 cm diameter). Subsequent recordings were made annually in autumn when the survival and size of existing plants were recorded along with any seedling recruitment.

Calculations

Basal area of *Aristida* spp. was calculated on an individual quadrat basis as the area occupied by all *Aristida* spp. plants in the quadrat by assuming plants to be circular. (When the plant was not circular, the diameter was assumed to be the mean of the 2 diameters measured for that plant). Mean plant size was determined as the mean area covered per plant and was calculated by dividing the total basal area per quadrat by the number of individual plants (incorporating the number of segments making up each of these plants) in that quadrat.

Plant turnover (number and basal area) was calculated as 1 minus the fraction of the population not turning over during the period of the study expressed as a percentage (after O'Connor 1994). The fraction not turning over was the number of individual plants or basal area present in 1990 and still present in 1996.

Statistical analysis

The 0.9 beasts/ha stocking rate treatment was excluded from all statistical analyses because it was not present for the native pasture treatments and was not replicated for the legume-oversown native pasture treatments. However, results from this treatment have been included for illustrative purposes.

Data were analysed by residual maximum likelihood (REML) with models including the fixed effects of pasture type (native pasture and oversown native pasture), land class (silver-leaved ironbark and narrow-leaved ironbark) and stocking rate (0.3 and 0.6 beasts/ha) and the random effects of replicate and paddocks within replicate. Significance of effects in the model would normally be tested by the Wald statistic. However, the Wald statistic has an asymptotic chi-squared distribution and tends to lead to an upward bias in the significance levels for smaller data sets. Therefore, an approximate F-test based on the Wald statistic was used to test effects in the model. Further details are presented in Orr *et al*. (2004a).

Plant survival was analysed using a proportional hazards survival model (Cox 1972).

Results

Seasonal conditions

The overriding climatic condition throughout this study was drought with 6 consecutive years of below average rainfall (Figure 1). Overall, the site experienced moderate drought (395–441 mm received in 12 months) for 39 months and severe drought (less than 395 mm received in 12 months) for 21 months as determined by RAINMAN (Clewett *et al*. 1994). By 1993, the previous 4 consecutive growing seasons had been the driest since district rainfall records commenced in 1887. Furthermore, total rainfall for the 5 years to June 1994 was the lowest for any continuous 5-year period. Thus, the results should be interpreted accordingly.

Plant turnover

Over the 6 years of this study, a total of 1409 individual *Aristida* spp. plants were encountered — 738 plants existing in 1990 plus 671 seedlings recorded between 1991 and 1996. Mean turnover rate for plant number was 60.3% while the turnover rate for basal area was 60.7% with no differences (P>0.05) due to either land class, stocking rate or pasture type (Table 1). Despite this, there was a general trend for turnover to increase with stocking rate for both plant density and basal area.

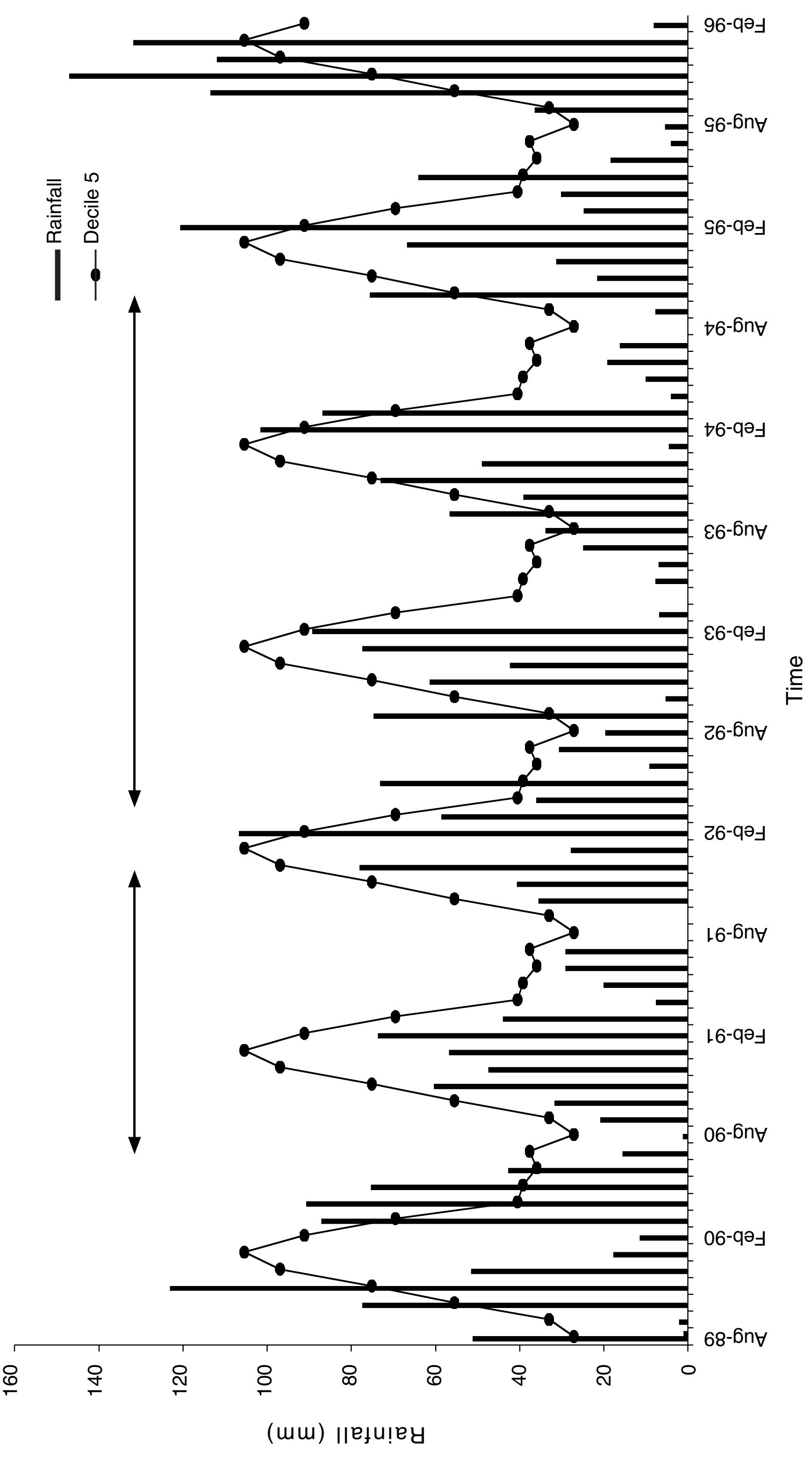

Figure 1. Monthly rainfall recorded at "Glenwood" (bars) between August 1989 and February 1996 compared with Decile 5 rainfall (continuous). Arrows (⟷) indicate times of drought during the experimental period as defined by RAINMAN (Clewett *et al*. 1994).

Table 1. Plant turnover[1] of plant number and basal area of *Aristida* spp. between 1990 and 1996 in relation to land class, stocking rate and pasture type in *H. contortus* pasture in southern Queensland.

Variable	Treatment	Plant number	Basal area
Land class	Narrow-leaved ironbark	59.8a[2]	55.4a
	Silver-leaved ironbark	60.8a	66.0a
Stocking rate	0.3 beasts/ha	53.5a	49.3a
	0.6 beasts/ha	67.1a	72.1a
	0.9 beasts/ha	88.9[3]	95.7
Pasture type	Native pasture	61.9a	62.2a
	NP + legume	58.8a	59.2a

[1] Plant turnover for plant number and basal area was calculated as 1 minus the fraction of the population not turning over during the period of the study expressed as a percentage (after O'Connor 1994). The fraction not turning over was the number of individual plants or basal area present in 1990 and still present in 1996.
[2] Within parameters, values followed by the same letter are not significantly different (P>0.05).
[3] Data included for completeness only.

Population density

The density of *Aristida* spp. increased sharply between 1990 and 1991, fell rapidly between 1991 and 1992 and then declined slightly until 1996. There were no differences (P>0.05) in density between the 2 land classes (Figure 2a). However, plant density was inversely related to stocking rate with the only significant (P<0.05) difference between 0.3 and 0.6 beasts/ha being in 1994 (Figure 2b). There were no differences due to legume oversowing (Figure 2c).

Seedling recruitment

Large differences in recruitment of *Aristida* spp. seedlings occurred among years with the highest level of recruitment in 1991. Recruitment was greater (P<0.05) in the narrow-leaved ironbark than in the silver-leaved ironbark land class in 1992 and 1994 (Figure 3a). Stocking rate had no significant (P>0.05) effect on recruitment (Figure 3b). While levels of recruitment on the 2 pasture types varied, the difference was significant (P<0.05) only in 1995, being higher on native pasture (Figure 3c).

Plant survival

There were few major differences in the survival of either original *Aristida* plants or the 1991 seedling cohort (Figure 4). (Data for 1992–1995 seedling cohorts are not presented because of low seedling numbers). Survival of the original plants was unaffected by either land class or legume oversowing (Figures 4a, 4c) although the survival of these plants was reduced (P<0.05) at 0.6 compared with 0.3 beasts/ha stocking rate (Figure 4b). For the 1991 seedling cohort, survival was higher (P<0.05) in the narrow-leaved ironbark than the silver-leaved ironbark land class (Figure 4d) but was not influenced by either stocking rate or legume oversowing (Figures 4e, 4f).

Changes in basal area

Basal area of *Aristida* spp. declined from 0.56% in 1990 to 0.33% in 1992 and then remained more or less constant until 1996 (Figure 5). Basal area was greater (P<0.05) on the silver-leaved ironbark in 1990 but differences were not significant between land classes subsequently (Figure 5a). From 1992 onwards, basal area of *Aristida* spp. was higher (P<0.05) at 0.3 than at 0.6 beasts/ha (Figure 5b). Basal area was lowest at 0.9 beasts/ha throughout but these differences could not be tested statistically. For pasture type, *Aristida* spp. basal area was lower (P<0.05) with legume oversowing at the initial recording in 1990 but differences between pasture types were not different (P>0.05) after that date (Figure 5c).

Change in plant size

Between 1990 and 1996, the original *Aristida* spp. plants changed little in size at 0.3 beasts/ha and, although plants at 0.6 beasts/ha declined in size, these differences were significant (P<0.05) only in 1994 (Figure 6b). The original *Aristida* spp. plants declined in size substantially at 0.9 beasts/ha. Neither land class nor pasture type influenced the size of these original plants (Figures 6a, 6c). Plants recruited in 1991 continued to increase in size with time and there was no stocking rate effect evident between 0.3 and 0.6 beasts/ha although plant size was markedly reduced at 0.9 beasts/ha after 1993 (Figure 6e). Neither land class nor pasture type influenced the size of this 1991 cohort (Figures 6d, 6f).

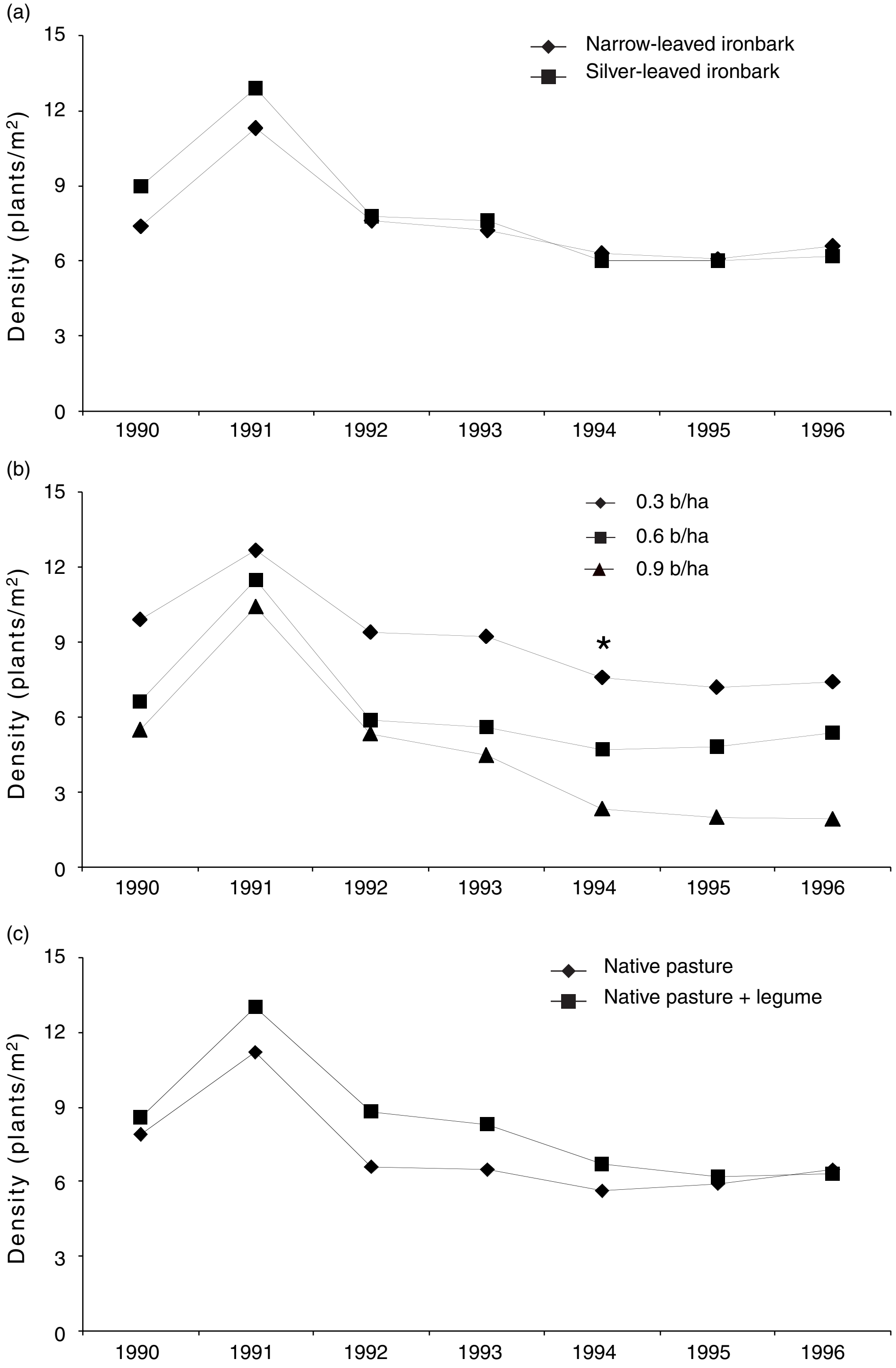

Figure 2. Changes in density of *Aristida* spp. measured in autumn in relation to: (a) land class; (b) stocking rate; and (c) legume oversowing in *H. contortus* pasture in southern Queensland. Within years, asterisks indicate values that are significantly ($P<0.05$) different. Data for the unreplicated 0.9 beasts/ha stocking rate are included for completeness only.

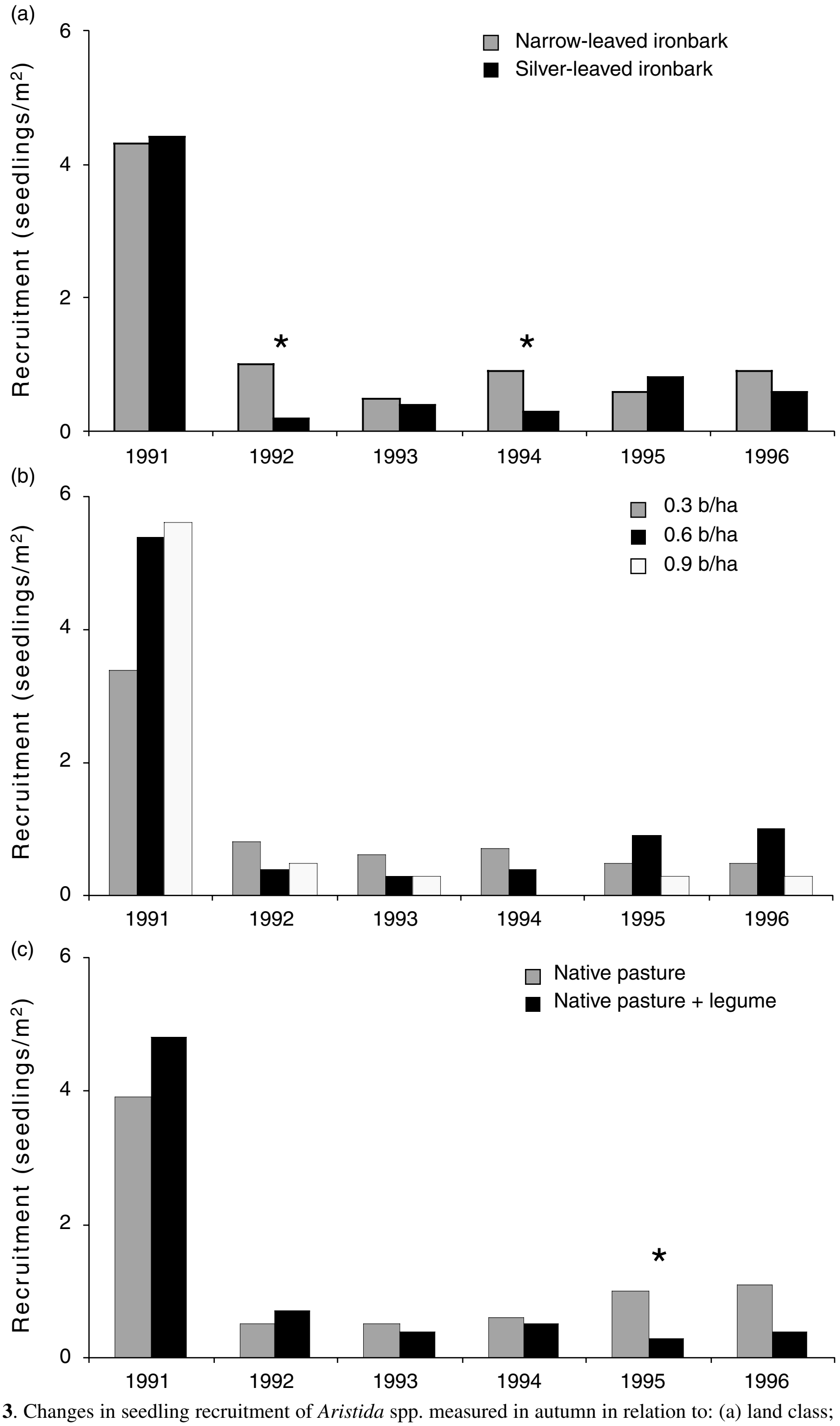

Figure 3. Changes in seedling recruitment of *Aristida* spp. measured in autumn in relation to: (a) land class; (b) stocking rate; and (c) legume oversowing in *H. contortus* pasture in southern Queensland. Within years, asterisks indicate values that are significantly ($P<0.05$) different. Data for the unreplicated 0.9 beasts/ha stocking rate are included for completeness only.

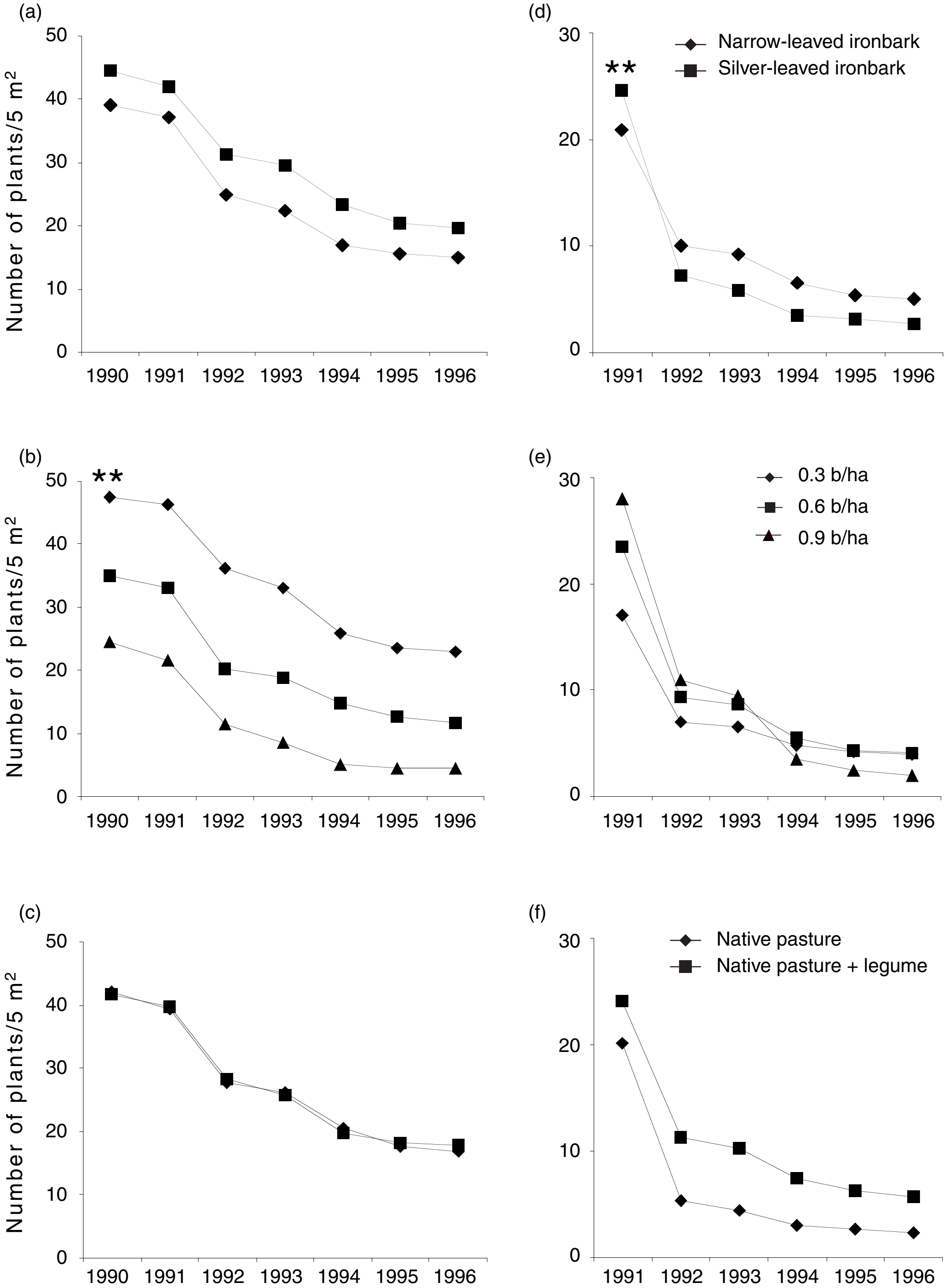

Figure 4. Changes in the numbers of original *Aristida* spp. plants in relation to: (a) land class; (b) stocking rate; and (c) legume oversowing, and of the 1991 seedling cohort in relation to: (d) land class; (e) stocking rate; and (f) legume oversowing in *H. contortus* pasture in southern Queensland. Within years, asterisks indicate values that are significantly (P<0.05; P<0.01) different. Data for the unreplicated 0.9 b/ha stocking rate are included for completeness only.

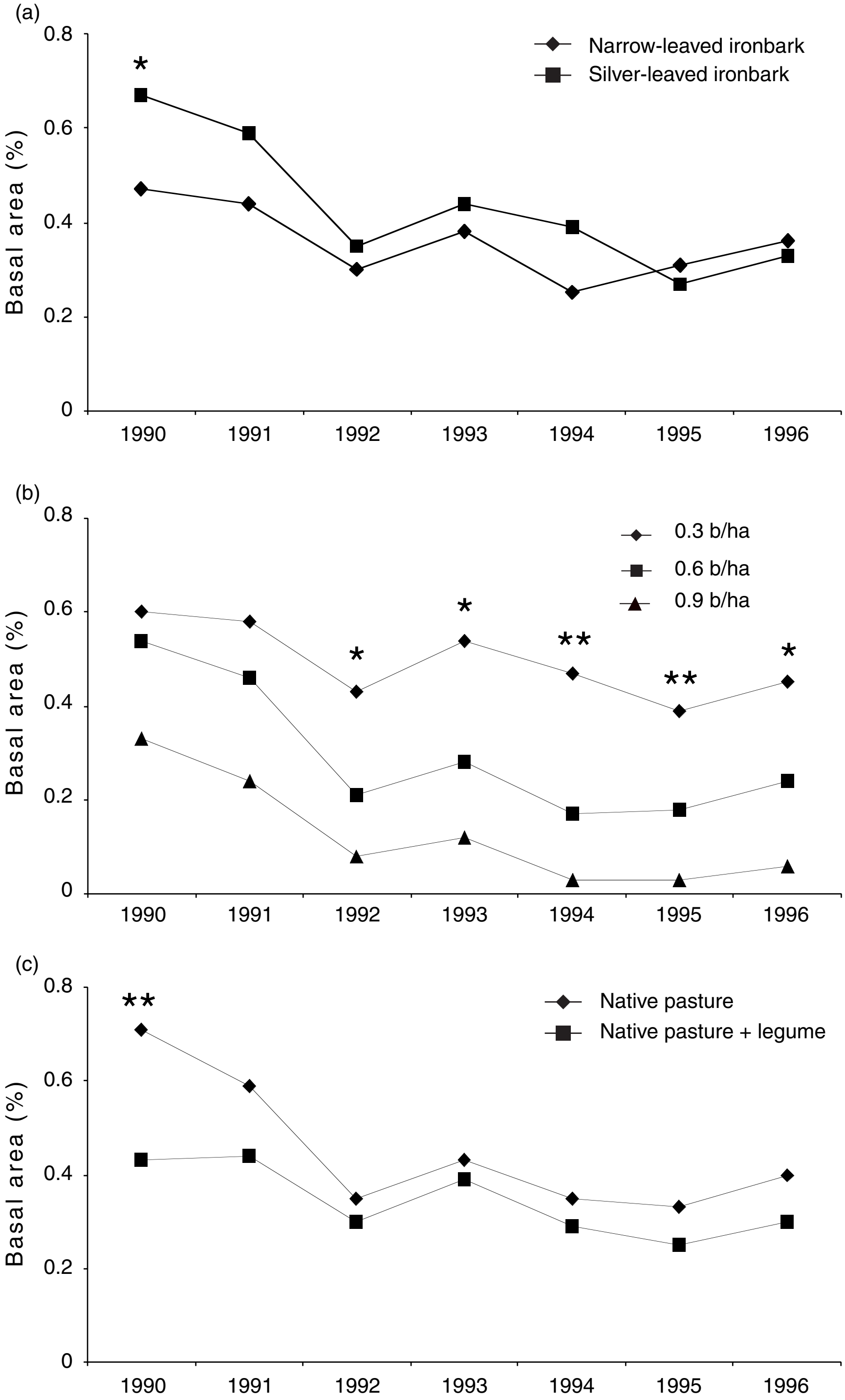

Figure 5. Changes in the basal area of *Aristida* spp. in autumn in relation to: (a) land class; (b) stocking rate; and (c) legume oversowing in *H. contortus* pasture in southern Queensland. Within years, asterisks indicate values that are significantly ($P<0.05$; $P<0.01$) different. Data for the unreplicated 0.9 beasts/ha stocking rate are included for completeness only.

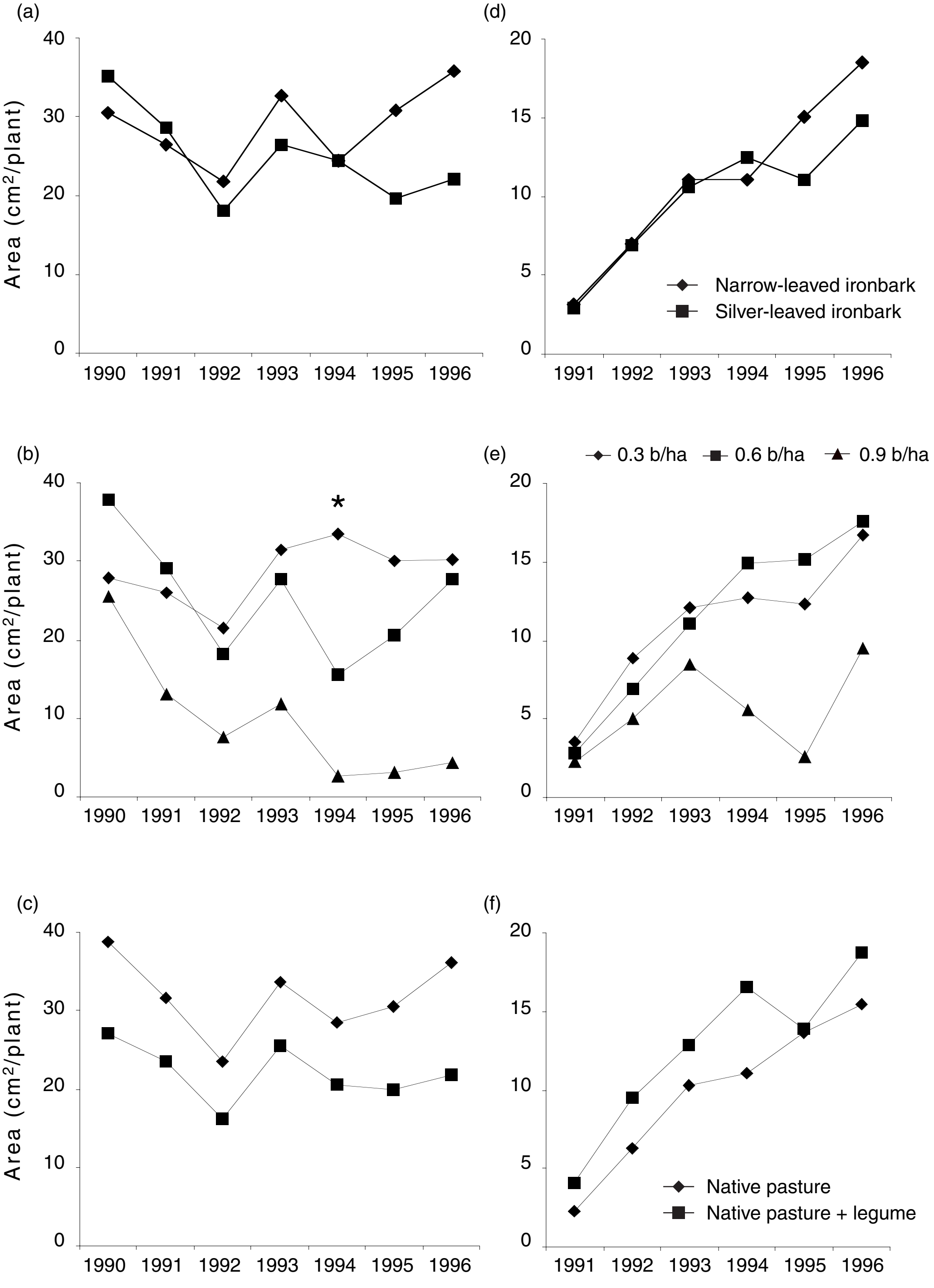

Figure 6. Changes in mean plant size of original *Aristida* spp. plants in relation to: (a) land class; (b) stocking rate; and (c) legume oversowing, and of the 1991 seedling cohort in relation to: (d) land class; (e) stocking rate; and (f) legume oversowing in *H. contortus* pasture in southern Queensland. Within years, asterisks indicate values that are significantly ($P<0.05$) different. Data for the unreplicated 0.9 beasts/ha stocking rate are included for completeness only.

Discussion

This study has shown that landscape position, and legume oversowing had minimal impact on the population dynamics of *Aristida* spp. in these *H. contortus* pastures. However, stocking rate did have some effects. Changes in plant density and basal area of *Aristida* spp. reflected differences in both the survival of existing plants and the recruitment of seedlings, and stocking rate had the greatest impact with reduction in basal area as stocking rate increased. Furthermore, despite the lack of replication, there was a consistent trend for the *Aristida* spp. population to be most impacted by the 0.9 beasts/ha stocking rate.

Species identification

Initially, we grouped all *Aristida* plants into the single classification *Aristida* spp. because of the difficulties of identifying closely related species in the field. However, McIntyre (1996) classified the different *Aristida* species at "Glenwood" into either the common "coarse-leaved" or "fine-leaved" taxa. Subsequently, we classified individual plants of *Aristida* spp. in the permanent quadrats as either "coarse" or "fine" and then examined the responses of the 2 taxa to the treatments imposed. There were no apparent differences between these 2 groups so we discuss the impact of the treatments in terms of *Aristida* spp. as a whole.

Impact of treatments

Clearly, this grazing study failed to run for sufficient time to detect major changes in composition of the vegetation (Orr *et al*. 2004a). Nevertheless, reduction in basal area and survival of the original plants with increasing stocking rate indicates that high stocking rates reduced *Aristida* spp. However, this finding is not consistently supported by plant density or recruitment data or survival of the 1991 seedling cohort. This reduction in *Aristida* spp. with increasing grazing pressure contrasts with other data which indicate that *Aristida* spp. increase with increasing grazing pressure. For example, Orr *et al*. (1997) suggest that *Aristida* spp. replace *H. contortus* under heavy grazing although an alternative explanation may be that the high *Aristida* spp. yields reflect the absence of spring burning in the years prior to that study. [The impact of burning on *Aristida* spp. at this "Glenwood" site is reported in Orr (2004).]

Basal area of *Aristida* spp. (mainly *A. armata*) increased with increasing grazing pressure in *Acacia aneura* (mulga) woodland in south-west Queensland (Orr *et al*. 1993), while *A. leptopoda* (white speargrass) was most common under heavy grazing in *Dichanthium sericeum* (Queensland bluegrass) pastures (Bisset 1960; Jacobsen 1981) and *A. bipartita* increased under heavy compared with light grazing in southern Africa (O'Connor 1994). In contrast, *A. latifolia* (feathertop wire-grass) was most common under light grazing in *Astrebla* (Mitchell grass) grasslands particularly during years of above average summer rainfall (Lee *et al*. 1980).

This study suggests that seedling recruitment of *Aristida* differs markedly between years and is related to differences between years rather than effects of the treatments used in this study (Figure 3). Estimates of the soil seed bank of *Aristida* spp. in spring in this study showed very few seeds (0–10 seeds/m^2) at that time although substantial seed of *H. contortus* was present in the soil seed bank (Orr *et al*. 2004b). Relatively little is known of the recruitment of *Aristida* spp., although Campbell (1996) demonstrated that *A. ramosa* produces viable seed soon after the opening summer rainfall, which can germinate and establish later in the same summer. This may explain the low reserves of seed remaining in the soil when we collected our soil cores during the spring. On this basis, the large differences in *Aristida* seedling recruitment measured in this study may reflect differences in summer rainfall which resulted in different levels of seedling establishment.

Neither land class nor legume oversowing had any consistent effects on the population dynamics of *Aristida* spp. Plants belonging to the "coarse" taxa were more common in the narrow-leaved ironbark, whereas plants of the "fine" taxa were more common in the silver-leaved ironbark land class as previously reported for this site (McIntyre 1996). However, this difference in the distribution of these 2 taxa between the 2 land classes does not explain the higher seedling recruitment in both 1992 and 1994 in the narrow-leaved compared with the silver-leaved ironbark land class.

Turnover rates for plant numbers in the current study are higher than those for *A. bipartita* in southern Africa (O'Connor 1994). Furthermore, rates in southern Africa were higher at light than at heavy grazing pressure whereas the current study indicates the reverse trend, with the *Aristida* population decreasing with increasing grazing pressure. Turnover rates for basal area of 53 and 64% for heavy and light grazing in southern Africa (O'Connor 1994) are similar to the 72.1 and 49.3% at 0.6 and 0.3 beasts/ha, respectively, in the current study but the 95.7% rate at 0.9 beasts/ha is much higher than that for southern Africa. The positive turnover figures for basal area of *Aristida* spp. in this study contrast with the negative figures for *H. contortus* recorded in the same quadrats in the silver-leaved ironbark land class, the 0.3 beasts/ha stocking rate and the native pasture treatments (Orr *et al*. 2004a). Clearly, *Aristida* plants were unable to increase in size in the later years of this study as occurred with *H. contortus*.

Comparison of Aristida *spp. and* H. contortus *population dynamics*

It is interesting to compare the population dynamics of *Aristida* spp. further with that of *H. contortus* in these same quadrats (Orr *et al*. 2004a). Averaged across all treatments for each year between 1990 and 1996, the density of *H. contortus* changed more than that of *Aristida* spp. (Figure 7a) due mainly to a greater range in the annual recruitment of *H. contortus* than of *Aristida* spp. (Figure 7b). Few differences were apparent between the 2 species in survival of either the original or 1991 recruited plants, although the apparently high reduction in survival between 1991 and 1992 (Figure 7c), probably due to drought, is reflected in reduced plant density of both species between 1991 and 1992

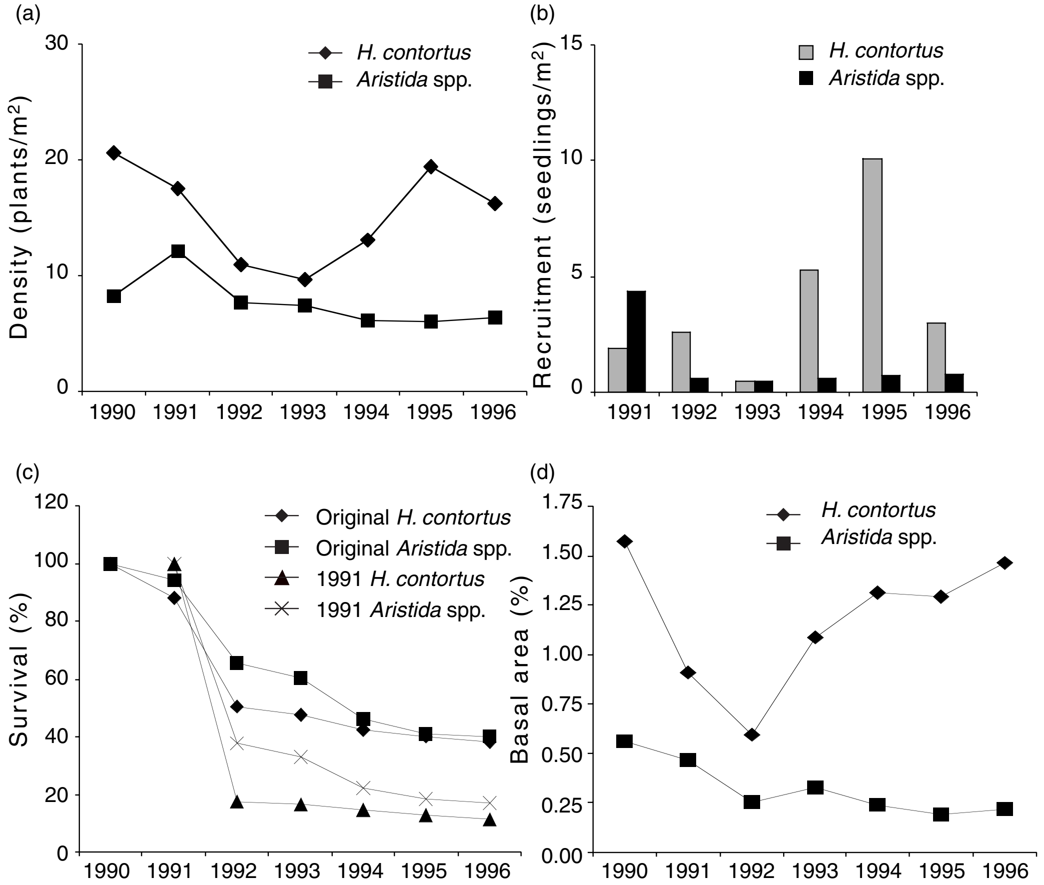

Figure 7. A comparison of *H. contortus* and *Aristida* spp. population parameters for: (a) plant density; (b) seedling recruitment; (c) survival of the original and 1991 cohort plants; and (d) basal area of the original plants between 1990 and 1996 in *H. contortus* pastures in southern Queensland.

(Figure 7a). There were no differences in overall turnovers for plant numbers, which were 71% and 65% for *H. contortus* and *Aristida* spp., respectively. However, as discussed above, there were large differences in overall turnover for basal area with 3% for *H. contortus* compared with 65% for *Aristida* spp. This highlights the failure of the 1990 original *Aristida* spp. plants to increase in basal area, as did the *H. contortus* plants, particularly after 1992 (Figure 7d).

Implications for grazing management

The results from this study suggest that, in the absence of fire, the populations of *Aristida* spp. in *H. contortus* pastures in southern Queensland are highest and plants are larger under light grazing, while seedling recruitment is somewhat episodic.

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