Wildlife Research, 1996, **23**, 687–96

Trends in Numbers and Changes in the Distribution of Feral Goats (*Capra hircus*) in the South Australian Pastoral Zone

A. R. Pople[A], *G. C. Grigg*[A], *S. C. Cairns*[B], *P. Alexander*[C], *L. A. Beard*[A] *and R. P. Henzell*[D]

[A]Department of Zoology, University of Queensland, Qld 4072, Australia.
[B]Department of Zoology, University of New England, Armidale, NSW 2351, Australia.
[C]South Australian Department of Environment and Natural Resources, GPO Box 1047, Adelaide, SA 5001, Australia.
[D]Animal and Plant Control Commission, GPO Box 1671, Adelaide, SA 5001, Australia.

Abstract

Trends in numbers and changes in the distribution of feral goats in the South Australian pastoral zone (217300 km^2) during 1978–94 were determined by winter aerial surveys. Only the presence or absence of goats on sample units was scored between 1978 and 1988. On the assumption of a random distribution of goat groups, these indices were transformed to densities of goat groups. Between 1989 and 1994 actual goat numbers were recorded on each sample unit, allowing goat density to be estimated. Goats were consistently at their highest densities in the south-east of the pastoral zone, a region dominated by open mallee scrub and chenopod shrubland. Densities of goat groups fluctuated from a low in 1984, following a drought, to a peak in 1990, following above-average rainfalls, when there were an estimated 193700 ± 29600 goats in the pastoral zone. This estimate is conservative because it is uncorrected for the visibility bias associated with sighting groups and undercounting their sizes. The estimate also excludes the Flinders Ranges for which a similar number of goats has been estimated.

Introduction

Feral goats in Australia are at their highest densities in the arid and semi-arid rangelands (Wilson *et al.* 1992), where they are considered a significant agricultural and environmental pest (Parkes *et al.* 1996). Within these rangelands, the distribution and abundance of goats has been determined from aerial surveys conducted in New South Wales and Queensland during 1992 (Southwell *et al.* 1993) and in Western Australia during 1987 and 1990 (Southwell and Pickles 1993). Southwell and Pickles (1993) reported on a population that had increased in numbers at a rate of 18% per annum between two aerial surveys, despite a considerable commercial harvest during that period. Furthermore, these goats had increased their distribution between surveys. This result, together with anecdotal evidence (Alexander 1992), has raised concerns about a general increase in feral goat numbers and an expansion of their range in continental Australia. Two questions can therefore be posed. First, are feral goats increasing in distribution and abundance over the long term? Second, can any observed increase be simply interpreted as part of a response to a fluctuating environment, with numbers fluctuating around a stable mean?

This paper adds to the knowledge of the distribution and abundance of feral goats in the arid and semi-arid rangelands of Australia by reporting on goat densities within the South Australian pastoral zone. Furthermore, because aerial surveys have been undertaken annually in the South Australian pastoral zone since 1978, an assessment of the changes in numbers and distribution of goats in relation to the environment is possible.

Methods

Study Area

The South Australian pastoral zone is approximately 282000 km^2 in area and extends from the New South Wales and Victorian borders in the east, onto the Nullarbor plain in the west and the Eyre Peninsula

1035-3712/96/060687$05.00

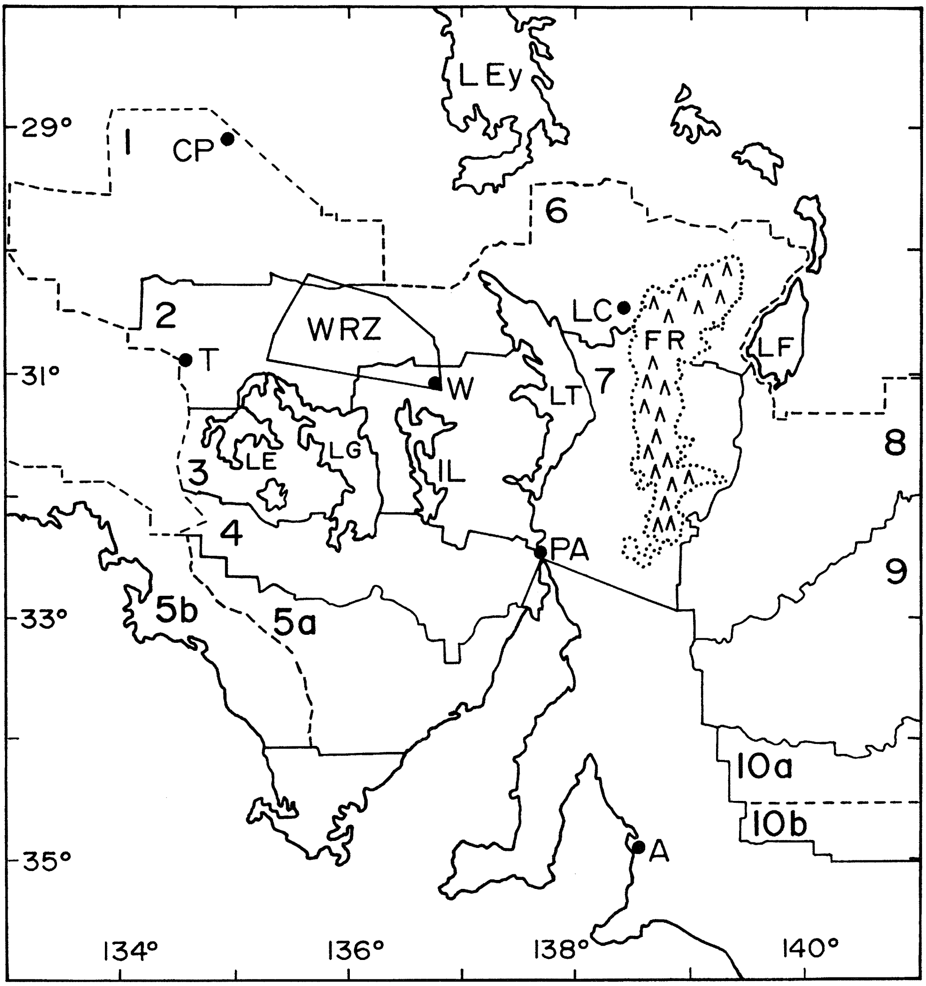

Fig. 1. The pastoral zone of South Australia showing the SADENR kangaroo management zones. Management zones 5b and 10b were not surveyed, nor were the Flinders Ranges above 500 m. The dingo-proof fence which bounds the pastoral zone in the north and the west is shown as a dashed line. Other geographical features are coded by the following abbreviations: A, Adelaide; CP, Coober Pedy; FR, Flinders Ranges; IL, Island Lagoon; LC, Leigh Creek; LE, Lake Everard; LEy, Lake Eyre; LF, Lake Frome; LG, Lake Gairdner; LT, Lake Torrens; PA, Port Augusta; T, Tarcoola; W, Woomera; WRZ, Woomera Restricted Zone.

in the south (Fig. 1). It is bounded in the north, the east and the west by a dingo-proof fence. The major form of land use in the pastoral zone is extensive livestock grazing, predominantly sheep. Other land-use practices such as grain growing and horticulture are restricted to the southern extremes of the zone. Most of the Eyre Peninsula is cultivated land, was surveyed rarely, and was therefore excluded from the analysis. Areas in the Flinders Ranges above 500 m were not surveyed at all.

The South Australian pastoral zone has been divided into ten kangaroo management zones (KMZs) by the South Australian Department of Environment and Natural Resources (SADENR) (Fig. 1), the areas of which are given in Cairns and Grigg (1993). Only eight of the ten management zones were considered in the analysis, with KMZs 5a and 10a being excluded, leaving an area of 217 300 km^2. The management zones are broadly based on the environmental provinces and regions delineated by Laut *et al.* (1977). Brief descriptions of the management zones used in this study are given below.

KMZ 1 and **KMZ 6** are dominated by gibber plains with some low escarpments and sand sheets or dunes. These plains are sparsely vegetated by a predominantly low shrubland of saltbush (*Atriplex* spp.) and bindyi (*Sclerolaena* spp.), but there are patches of low open woodland of mulga and mallee.

KMZ 2 comprises plains interspersed with sand dunes. It is dominated by tall mulga shrubland and chenopod shrubland.

KMZ 3 is characterised by the large salt lakes around which are undulating plains with low open mulga woodlands and chenopod shrublands.

KMZ 4 features the Gawler Ranges which are covered by woodland dominated by myall, mallee shrubland and low chenopod shrubland.

KMZ 7 is dominated west of the Flinders Ranges by plains with closely spaced dunes. The vegetation is dominated by low chenopod shrubland and low *Acacia* woodland.

KMZ 8 is dominated in the north by plains with low chenopod shrublands and low open woodlands of mulga. In the south, tall *Acacia* shrublands cover undulating plains, rounded hills and narrow ridges.

KMZ 9 is dominated in the south by open mallee scrub and chenopod shrubland covering an undulating plain with widespread dunes. In the north is the Olary upland that is shared with KMZ 8.

Average annual rainfalls in the pastoral zone range from 400 mm in the south of the zone to less than 150 mm in the north-west. Along this gradient from the south to the north-west, rainfall variability and evaporation increase, and rainfall becomes less seasonal by losing its winter peak. The Mediterranean climate of the south is replaced in the north by one of cold winters and very hot summers.

Aerial Survey

Since 1978, goats have been counted during winter (July–August) aerial surveys flown each year to monitor numbers of kangaroos. Observers seated on either side of a high-winged aircraft (Cessna 182) scanned a 200-m-wide strip on the ground delineated by markers on the wing struts of the aircraft. Surveys were flown at a height of 76 m and a speed of 186 km h^{-1}. During a 7-s break, observers recorded the number of animals seen in the previous 97 s. Data were therefore recorded for 1-km^2 sample units on either side of the aircraft. Transects were spaced 28 km apart, equivalent to two flight lines across a half-degree square block (one half-degree latitude by one half-degree longitude), and were flown east–west across the pastoral zone. This represents a sampling intensity of 1·3%, which is twice that used for broadscale kangaroo surveys conducted by fixed-wing aircraft in other States (J. Caughley *et al.* 1984; Southwell and Pickles 1993; Southwell *et al.* 1993). Technical details of the survey format were reported by Caughley and Grigg (1981). The means and standard errors of goat densities and numbers for KMZs and half-degree square blocks were calculated by the ratio method of estimation (Caughley 1977). Densities were uncorrected for visibility bias. The extent to which goats are undersampled under these survey conditions has yet to be adequately determined. An application of line transect methodology to aerial surveys of goats by Southwell (1996) suggested a negative bias of at least 30–40%. Within the context of this paper, it is the value of such density estimates as a relative measure that is important; for this, bias needs to be consistent. However, a long time series of data will diminish the influence of the aberrant results of any particular year.

Prior to 1989, only the presence or absence of goats in each sample unit was recorded, providing an index of abundance that is likely to have a non-linear relationship with density (Caughley 1977). This frequency can be converted to a density if it is assumed that goat groups or herds are distributed at random with respect to the sampling unit. Such a distribution can be tested for by fitting a Poisson distribution to the observed frequency of groups per sampling unit. Although data for goats are not available, similar surveys have shown that groups of emus are randomly distributed (Caughley and Grice 1982). On the basis of this untested assumption, the proportion of units containing goat groups (f) can be related to group density (d) by the expression $d = -\ln(1 - f)$ (Caughley and Grice 1982). Estimates of goat group density were calculated for half-degree square blocks and for the KMZs for 1978–94. If goat groups tended to be clumped, then these estimates of group density will be negatively biased (Caughley 1977). However, what is more critical is whether this estimate of group density can be used as an index of goat density, allowing a trend over time to be examined.

Analysis

The relationship between goat group density and goat density in half-degree square blocks for 1989–94 was examined by regression analysis. Comparisons between the relationships for each of the years 1989–94 were conducted by an analysis of covariance (Zar 1984). Overall trends in goat group density for 1978–94 on each KMZ were also compared by an analysis of covariance. Linear regressions were fitted to the natural logarithms of the group density estimates for each KMZ. The slopes of these regressions represent an estimate of the average exponential rate of increase (r) over that period (Caughley and Sinclair 1994).

Rainfall records were obtained from the Bureau of Meteorology for recording stations within each KMZ. Within each zone, annual rainfalls were averaged across these recording stations and expressed as relative rainfalls: proportions of the long-term average annual rainfalls. Changes in goat density and goat group density can be described by yearly exponential rates of population increase, calculated as the natural logarithm of the ratios of successive density estimates. For each KMZ, correlations were examined between r and both 6 and 12 months rainfall (absolute) falling at 0, 6, 12, 18 and 24 months prior to the second survey from which r was calculated. For each year, goat group size was estimated to be the slope of the regression line describing the relationship between goat density and goat group density. Correlations were then examined between group size and the above intervals of rainfall.

Results

Goats were commonly observed in KMZs 3, 4, 6, 8 and 9, but only infrequently sighted in KMZs 1, 2 and 7. Estimates of goat density in KMZs 3, 4, 6, 8 and 9 for 1989–94 are shown in Fig. 2. The highest densities were clearly in KMZ 9, where they fluctuated between 2 and 4 animals km^{-2}. With the exception of KMZ 6, these fluctuations were roughly mirrored in the lower densities of the other four management zones.

The estimated densities of goat groups in KMZs 3, 4, 6, 8 and 9 over the 17 years of aerial surveys are shown in Fig. 3. A similar pattern emerges, with the highest densities in KMZ 9. Goat group densities declined markedly on KMZ 9 following the drought in 1982–83, but rapidly recovered to pre-drought levels by 1985. In 1990, densities of goat groups increased dramatically in KMZs 4, 8 and 9, and these higher levels of density have generally been maintained up to 1994. This followed rainfall that was well above average in 1989 and 1992. Relative rainfalls averaged over KMZs 3, 4, 6, 8 and 9 for 1976–93 are shown in Fig. 4.

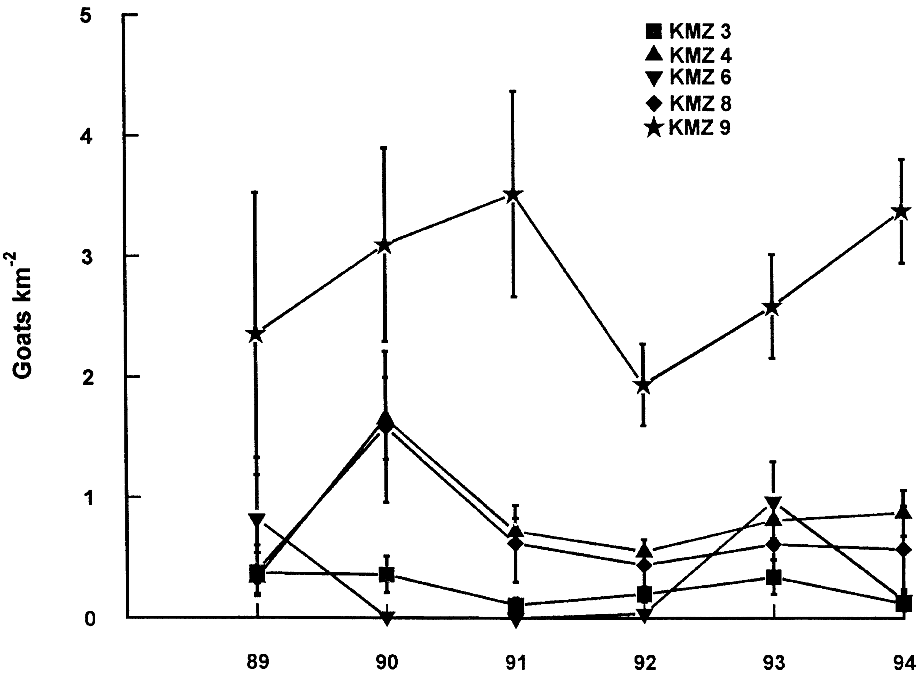

Fig. 2. Annual trends in goat densities (± s.e.) in five SADENR kangaroo management zones for 1989–94.

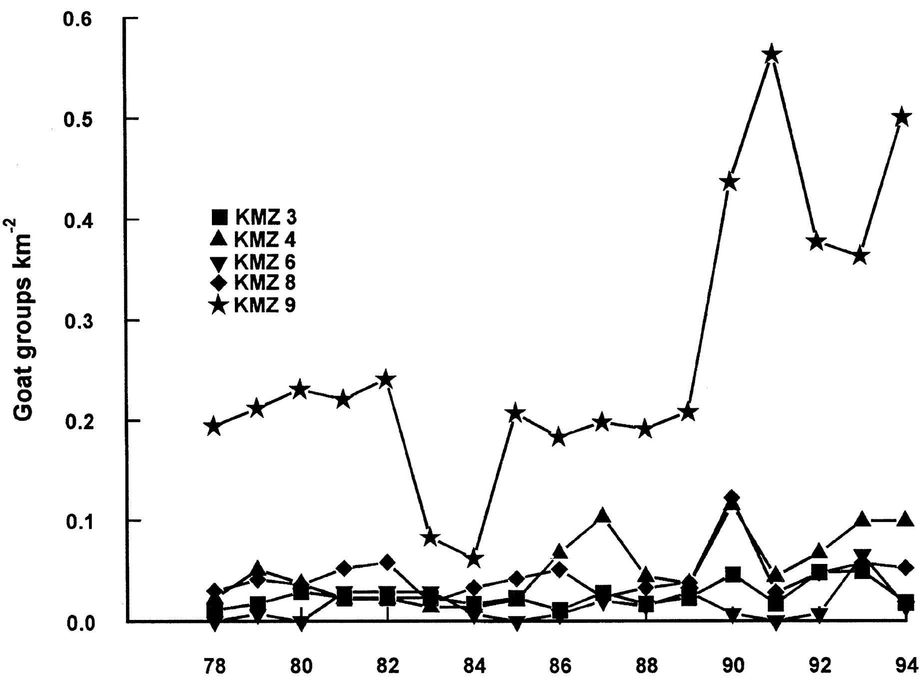

Fig. 3. Annual trends in the number of goat groups in five SADENR kangaroo management zones for 1978–94.

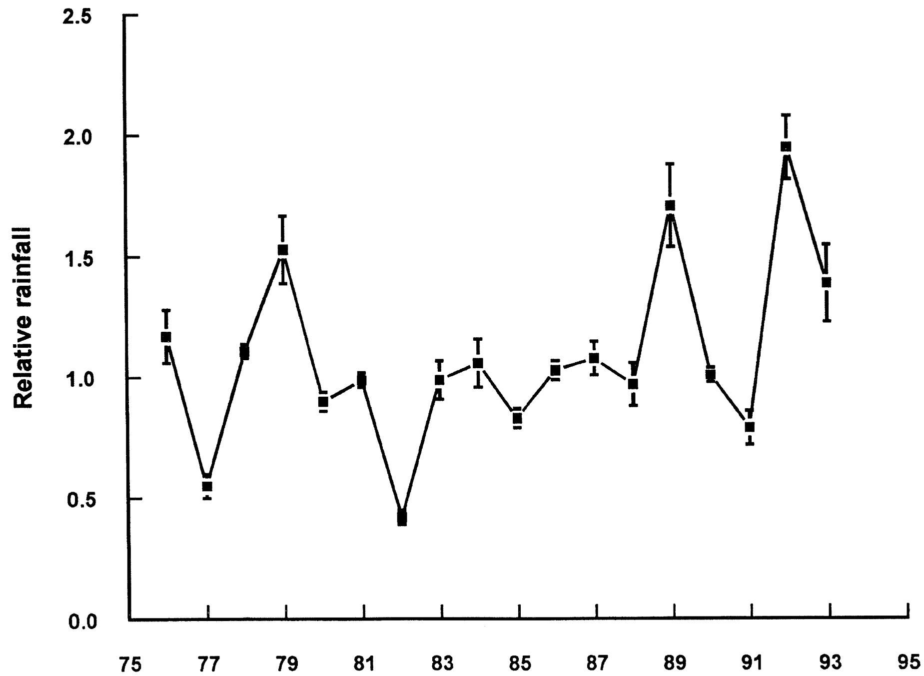

Fig. 4. Annual relative rainfalls between 1976 and 1993, averaged (± s.e.) across kangaroo management zones 3, 4, 6, 8 and 9.

The relationships between goat density (y) and goat group density (x) in half-degree square blocks for each of the years 1989–94 were all found to be significant ($P < 0.001$). An analysis of covariance resulted in an overall model with a separate slope (b) for each year ($F_{5,133} = 6.55$, $P < 0.001$). Because none of the intercepts was significantly different from zero ($F_{5,138} = 1.57$, $P > 0.1$), the resulting regressions were all adjusted to the form $y = bx$. The coefficients (b) of these regressions are given in Table 1. With the overall model explaining 59% of the variance in goat density, goat group density would appear to be a reasonable index of goat density. However, the different slopes in the model, and therefore the lack of consistency in the relationship, preclude estimation of actual goat densities from goat group densities for the years prior to 1989.

Table 1. Coefficients (b) and associated standard errors (s.e.) for the linear regressions ($y = bx$) of goat density (y) on goat group density for 1989–94

Year	b	s.e.
1989	12·81	1·46
1990	8·26	0·71
1991	4·69	0·58
1992	5·32	1·12
1993	7·61	0·97
1994	6·68	0·81

The relationships between the natural logarithm of goat group density (y) and the serial years of the study (x), 1978–94, were examined across KMZs 3, 4, 8 and 9. KMZ 6 was excluded from the analysis because of low densities including several zero values. An analysis of covariance resulted in a model with different intercepts ($F_{3,64} = 56.39$, $P < 0.001$), reflecting different overall group density in the four zones, but with a slope (b) common to all years as indicated by a non-significant interaction between serial year and management zone ($F_{3,60} = 1.59$, $P > 0.1$). This common slope (b = 0·05 ± 0·01) indicates that the average exponential rate of increase in goat group density over the 17 years was the same across KMZs 3, 4, 8 and 9.

The only positive association found between r and lagged rainfall was for goat groups on KMZ 9 and 12 months rainfall lagged 12 months (r = 0·53, $P < 0.05$). Goat group size was significantly correlated with only the 6 months rainfall falling immediately prior to a survey (r = 0·85, $P < 0.05$).

Table 2. Estimates of the total goat numbers in the South Australian pastoral zone (± s.e.) for 1989–94

Estimates exclude KMZs 5 and 10, and areas in the Flinders Ranges above 500 m

Year	Numbers
1989	106 600 ± 30 900
1990	193 700 ± 29 500
1991	123 400 ± 22 300
1992	78 600 ± 10 900
1993	136 200 ± 17 700
1994	125 100 ± 16 400

Table 3. Number of goats slaughtered at domestic and export abattoirs in South Australia during 1987–92 (Ramsay 1994)

Year	Numbers
1987–88	89 300
1988–89	82 500
1989–90	98 200
1990–91	161 100
1991–92	165 700

Estimated total numbers of goats in the South Australian pastoral zone for each of the years 1989–94 are given in Table 2. These population estimates are uncorrected for visibility bias and are therefore conservative. Available data on the statewide commercial harvest of goats for 1987–92 (Ramsay 1994) are given in Table 3. The increase in the commercial harvest appears to have coincided with an increase in the population size of goats in the pastoral zone. However, it also coincided with an increase in demand resulting from an expansion of the export market for goats. Compared with the population estimates in Table 2, the commercial harvest is particularly high, especially considering it does not include goats destroyed for pest mitigation. However, the estimates for the commercial harvest are for the entire state, not just the pastoral zone. In particular, the Flinders Ranges are a major source of goats for the commercial harvest. Extrapolating the results of aerial and ground surveys of areas within the Flinders Ranges, Alexander (1992) suggested that the number of goats in the Flinders Ranges equalled the number in the rest of the pastoral zone combined. It is difficult to quantify the numbers of goats destroyed solely for damage mitigation over this period. However, it is likely to have been localised, such as on national parks, and infrequent. Outside of national parks, non-commercial culling has largely been undertaken by recreational hunters. For these reasons the number of goats removed by non-commercial culling is probably substantially less than the commercial harvest.

The density distributions of goats within the pastoral zone are shown in Fig. 5. Densities within the half-degree square blocks have been averaged over 5-year periods, with the exception of the two low-density years associated with the drought, 1983 and 1984, which were grouped separately. For these four time periods, 1978–82, 1983–84, 1985–89, 1990–94, goats were present on 35, 24, 41 and 44% of the half-degree square blocks, respectively. This suggests that an increase in the distribution of goats has accompanied the overall increase in numbers. The 1990–94 distribution (Fig. 5*d*) shows seven blocks with goats present that had previously been unoccupied. However, a further nine blocks are unoccupied that had been occupied prior to 1990 (Fig. 5*a*–*c*).

Discussion

Goat densities reported here are comparable to those in the pastoral zones of New South Wales, Queensland and Western Australia, where an identical survey format was used. It must be stressed that all of these estimates are at best minimum estimates as they have been uncorrected for visibility bias. By combining these population estimates, and including an estimate for the Flinders Ranges equivalent to that for rest of the South Australian pastoral zone, these survey results yield a conservative estimate of 1·5–2 million goats in the semi-arid rangelands of Australia. This estimate falls within the range suggested by Wilson *et al.* (1992).

The distribution of goats within the pastoral zone indicates a close association with hilly areas (notably the Flinders Ranges, Gawler Ranges and Olary upland) and heavily timbered areas (in the south, but particularly the mallee country in the south-east). In Western Australia, Southwell and Pickles (1993) reported an increase in the percentage of one-degree square blocks with goats present from 28 to 36%, between aerial surveys in 1987 and 1990. This

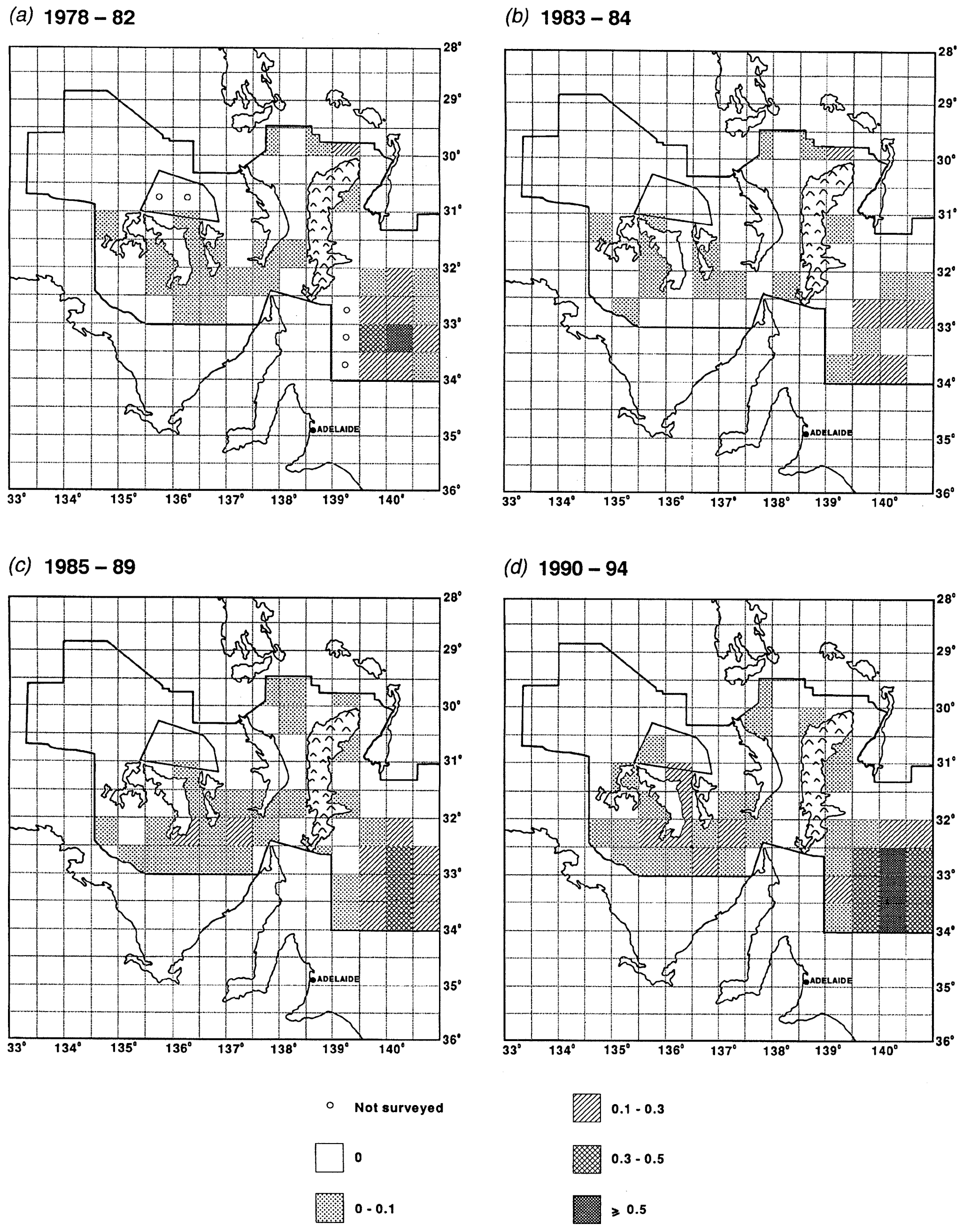

Fig. 5. Density distribution of goat groups (km^{-2}) in half-degree square blocks within the South Australian pastoral zone. *a*, 1978–82; *b*, 1983–84; *c*, 1985–89; *d*, 1990–94.

suggested an expansion in the geographical range of goats, particularly because goats had moved into areas where they had not previously been found. The suggestion from the South Australian data is that, while occupancy rates have increased in the last five years, there has not been an obvious range expansion. Furthermore, the ability of aerial surveys, with a sampling intensity of 1·3%, to record goats in half-degree square blocks will decline with density. Fluctuations in distribution are likely to be at least partly an artefact of such surveys.

The trends in numbers are similar to those for red kangaroos (Cairns and Grigg 1993) and emus (Pople *et al.* 1991) in the South Australian pastoral zone, and appeared to be influenced by rainfall. This similarity is not surprising. Parkes *et al.* (1996) suggested a maximum exponential rate of increase for feral goats in semi-arid South Australia of 0·43, based upon observed age distributions and fecundity rates, and a combination of observed and estimated survival rates. This rate is similar to empirical estimates for red kangaroos in this region (0·34–0·57, Bayliss 1987; 0·38–0·92, Cairns and Grigg 1993). Such rates are those expected when resources are not limiting, but not necessarily for a population with a stable age distribution which is unlikely in a fluctuating environment.

Group size in winter also appeared to be influenced by rainfall. While groups may join and divide during breeding and group size may increase with density, it seems that environmental factors also influence group dynamics. In a pastoral area in Western Australia, King (1992) found group size to be considerably variable, but observed no seasonal trend during a 2-year period. In arid areas, widespread rain produces a less patchy and more abundant food supply, resulting in a more even dispersion of red kangaroos (Newsome 1965). Goats appear to show the opposite response, with groups coalescing following good rains.

The extent to which commercial harvesting and culling operations have reduced the population size of goats, at least on a broad scale, is unclear. In a fluctuating environment, populations that are harvested at a constant, sustainable effort or rate will still fluctuate, although mean density is depressed (Caughley 1977). This appears to be the case for red kangaroos in South Australia (Pople and Cairns 1995). Social and economic factors aside, the extent to which a population can be reduced will depend upon the extent to which both the potential rate of increase is enhanced through a reduction in density and the rate of removal is reduced by declining density. That goat numbers have fluctuated in a manner similar to that of the other large wild herbivores in the pastoral zone, suggests that the commercial and non-commercial harvesting of goats represents a sustained-yield operation. Whether this harvest has achieved any pest control objectives (i.e. an adequate reduction in their damage) remains to be tested.

The estimates of density presented here are uncorrected for visibility bias. The problem of bias attributed to counting saturation in aerial surveys (Newsome *et al.* 1981; Dexter 1990) was recognised for goats by Southwell and Pickles (1993). They remarked that while group sightability is high, the size of groups may be substantially underestimated. Graham and Bell (1989) reported marked undercounting of group sizes of feral horses and donkeys in northern Australia. The large variability in group size may also reduce the precision of density estimates and the resulting trends. The high sightability of groups may make them amenable to double-counting from which correction factors could be derived, which has been undertaken for emus (Caughley and Grice 1982), and feral buffaloes, cattle, horses and donkeys (Bayliss and Yeomans 1989). Instead of tallying the number of goats seen in each unit, observers could record the number of groups and group sizes (with a tape recorder), enabling average group size to be determined (e.g. Bayliss and Yeomans 1989). Alternatively, group size could be determined from the ground or, if from the air, by an independent observer concentrating on that task, from photographs, or by circling a sample of groups (Caughley and Grice 1982).

Acknowledgments

We thank the numerous people who acted as observers on the surveys, including J. Caughley, M. Fletcher, T. Gerschwitz, P. Harlow, G. Ross and the late G. Caughley. Thanks also go to Lyn Pryor who drew the distribution maps. Finally, we thank SADENR who have funded the surveys since their inception in 1978. The comments of two anonymous referees were appreciated.

References

Alexander, P. (1992). Distribution and abundance of feral goats in South Australia. In 'Feral Goat Seminar Proceedings'. (Ed. L. W. Best.) pp. 6–10. (South Australian National Parks and Wildlife Service: Adelaide.)

Bayliss, P. (1987). Kangaroo dynamics. In 'Kangaroos: their Ecology and Management in the Sheep Rangelands of Australia'. (Eds G. Caughley, N. Shepherd and J. Short.) pp. 119–34. (Cambridge University Press: Cambridge.)

Bayliss, P., and Yeomans, K. (1989). Correcting bias in aerial survey population estimates of feral livestock in northern Australia using the double-count method. *Journal of Applied Ecology* **26**, 925–33.

Cairns, S. C., and Grigg, G. C. (1993). Population dynamics of red kangaroos (*Macropus rufus*) in relation to rainfall in the South Australian pastoral zone. *Journal of Applied Ecology* **30**, 444–58.

Caughley, G. (1977). 'Analysis of Vertebrate Populations.' (Wiley and Sons: London.)

Caughley, G., and Grice, D. (1982). A correction factor for counting emus from the air, and its application to counts in Western Australia. *Australian Wildlife Research* **9**, 253–9.

Caughley, G., and Grigg, G. C. (1981). Surveys of the distribution and density of kangaroos in the pastoral zone of South Australia and their bearing on the feasibility of aerial survey in large and remote areas. *Australian Wildlife Research* **8**, 1–11.

Caughley, G., and Sinclair, A. R. E. (1994). 'Wildlife Ecology and Management.' (Blackwell Scientific Publications: London.)

Caughley, J., Bayliss, P., and Giles, J. (1984). Trend of kangaroo populations in New South Wales, Australia. *Australian Wildlife Research* **11**, 415–22.

Dexter, N. (1990). Density dependent bias in aerial counts of magpie goose nests. *Australian Wildlife Research* **17**, 447–51.

Graham, A., and Bell, R. (1989). Investigating observer bias in aerial survey by simultaneous double-counts. *Journal of Wildlife Management* **52**, 1009–16.

King, D. (1992). Home ranges of feral goats in a pastoral area in Western Australia. *Wildlife Research* **19**, 643–9.

Laut, P., Heyligers, P. C., Keig, G., Loffler, E., Margules, C., and Scott, R. M. (1977). 'Environments of South Australia.' (CSIRO, Division of Land Use Research: Canberra.)

Newsome, A. E. (1965). The distribution of red kangaroos, *Megaleia rufa* (Desmarest), about sources of persistent food and water in central Australia. *Australian Journal of Zoology* **13**, 289–99.

Newsome, A. E., Dudzinski, M. L., and Low, W. A. (1981). Measuring bias in aerial surveys due to dispersion of animals. In 'Low Level Aerial Survey Techniques'. pp. 185–94. (ICLA Monograph No. 4: Addis Ababa.)

Parkes, J. P., Henzell, R. P., and Pickles, G. S. (1996). 'Managing Vertebrate Pests: Feral Goats.' (Australian Government Publishing Service: Canberra.)

Pople, A., and Cairns, S. (1995). Impact of harvesting on kangaroos. In 'Conservation Through Sustainable Use of Wildlife'. (Eds G. Grigg, P. Hale and D. Lunney.) pp. 224–9. (Centre for Conservation Biology, The University of Queensland: Brisbane.)

Pople, A., Cairns, S. C., and Grigg, G. C. (1991). Distribution and abundance of emus *Dromaius novaehollandiae* in relation to the environment in the South Australian pastoral zone. *Emu* **91**, 222–9.

Ramsay, B. J. (1994). 'Commercial Use of Wild Animals in Australia.' (Australian Government Publishing Service: Canberra.)

Southwell, C. J., and Pickles, G. S. (1993). Abundance, distribution, and rate of increase of feral goats in Western Australia. *The Rangeland Journal* **15**, 334–8.

Southwell, C., Weaver, K., Sheppard, N., and Morris, P. (1993). Distribution and relative abundance of feral goats in the rangelands of eastern Australia. *The Rangeland Journal* **15**, 331–3.

Southwell, C. (1996). Bias in surveys of feral goats in the rangelands of Western Australia. *The Rangeland Journal* **18**, 99–103.

Wilson, G., Dexter, N., O'Brien, P., and Bomford, M. (1992). 'Pest Animals in Australia: A Survey of Introduced Wild Animals.' (Bureau of Rural Resources, Department of Primary Industries: Canberra.)

Zar, J. H. (1984). 'Biostatistical Analysis.' 2nd Edn. (Prentice-Hall, Inc.: Englewood Cliffs, New Jersey.)

Manuscript received 5 April 1995; revised 19 February 1996; revised and accepted 3 July 1996