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AN EVALUATION OF A LONG-TERM FERAL GOAT CONTROL PROGRAM IN MOOTWINGEE NATIONAL PARK AND COTURAUNDEE NATURE RESERVE, FAR WESTERN NEW SOUTH WALES.

Andy Sharp[1,2], Kerry Holmes[1] and Melinda Norton[1,3]

[1] *NSW National Parks and Wildlife Service, PO Box 459, Broken Hill, NSW, 2880.*
[2] *Present address: Centre for Conservation Biology, Zoology Department, University of Queensland, Queensland, 4072.*
[3] *Present address: NSW National Parks and Wildlife Service, PO Box 707, Nowra, NSW, 2541.*

Abstract

Between January 1981 and September 1997, goat mustering and aerial culling was conducted on Mootwingee National Park and Coturaundee Nature Reserve, an area with high densities of goats (Southwell *et al.* 1993). The goat control campaign was initiated as a general management strategy to reduce the negative impacts of goats on native vegetation, aboriginal art sites and the endangered yellow-footed rock-wallaby (*Petrogale xanthopus*). During this period a total of 42,516 goats were removed (13,089 mustered, 29,427 shot). Between January 1988 and June 1995 it was possible to calculate population indices for goats using aerial culling data; Ln(number of goats shot/minute flying time+1). The study site was sub-divided into northern and southern blocks and population indices calculated for each block. Linear regression equations were fitted to the population indices plotted across time. The data suggest that despite the removal of considerable numbers of goats from both blocks of the study area (11,601, northern; 10,035, southern), there was no detectable decrease in goat numbers over the 1988-1995 period. For both blocks the slope of the regression line was negative and close to zero (-0.005, northern; -0.0003, southern). The results indicate that the impact of mustering and shooting was short-term and that the re-invasion rate by goats into the area was very high. In areas of high goat density, control measures need to be regular and conducted over a broad geographic area if goat numbers are to be effectively reduced. No detectable increase was noted in the yellow-footed rock-wallaby population during the period of intensive goat control.

Introduction

Since their introduction into Australia, feral goat (*Capra hircus*) numbers have increased markedly in many areas of the continent (Parkes *et al.* 1996). The largest populations exist within the arid and semi-arid regions, where the provision of artificial waters and the reduction of predator abundance (particularly the dingo) have removed these important limiting factors on goat numbers (Parkes *et al.* 1996). In the semi-arid rangelands, high densities of goats contribute significantly to total grazing pressure resulting in deleterious impacts on: native vegetation communities (Parkes *et al.* 1996, Landsberg and Stol 1996, Maas 1997), the abundance and distribution of native animals (Reeves 1992), soil stability (Mahood 1983, Henzell 1992) and economic returns for pastoralists (Henzell 1992, Parkes *et al.* 1996).

Mootwingee National Park (Mootwingee N.P.) and Coturaundee Nature Reserve (Coturaundee N.R.) are located within the semi-arid rangelands of western New South Wales, an area with high densities of feral goats (>3.1/km^2; Southwell *et al.* 1993). As part of their feral animal control program, the New South Wales National Parks and Wildlife Service (NSW NPWS) began feral goat mustering and culling on these reserves in 1981. The control program was initiated in an attempt to mitigate the impact of feral goats on native vegetation (see Mahood 1985), to protect Aboriginal art sites within caves and overhangs from the abrasive damage caused by horn rubbing and to reduce potential competition for food with the endangered yellow-footed rock-wallaby *Petrogale xanthopus*, which inhabits the northern ranges of the reserves (i.e. the Gap and Coturaundee Ranges). Lim *et al.* (1992) hypothesised that competition with feral goats for food (and possibly shelter sites) may be inhibiting the NSW population of the yellow-footed rock-wallaby, as the diets of both species within the study area have been documented to exhibit considerable overlap, particularly during drought (Dawson and Ellis 1979).

The aim of this study was to evaluate historical data on goat harvest operations to determine the long-term effects of regular control operations on a feral goat population located within a conservation area of relatively small size. In addition, the impact that goat control had on the population of yellow-footed rock-wallabies was assessed.

Methods

Mootwingee N.P. (68,900 ha) and Coturaundee N.R. (6688 ha) are located approximately 120 km north-east of Broken Hill (31°14'00"S, 142°19'00"E and 30°57'00"S, 142°40'00"E respectively). Mootwingee N.P. contains two mountain ranges, the Bynguano Range to the south and the Gap Range to the north, with an area of rolling downs lying between the two ranges (Fig. 1). Coturaundee N.R. lies 6 km to the north-east of Mootwingee N.P. and encompasses the Coturaundee Range (Fig. 1). Belah (*Casuarina cristata*)-rosewood (*Heterodendrum oleifolium*)-white cypress pine (*Callitris glaucophylla*) woodland communities dominate on the range systems, with river red gum (*Eucalyptus camaldulensis*) woodlands on the riverine plains and saltbush-bluebush (*Chenopod* spp.) shrublands on the rolling downs (Anon. 1989).

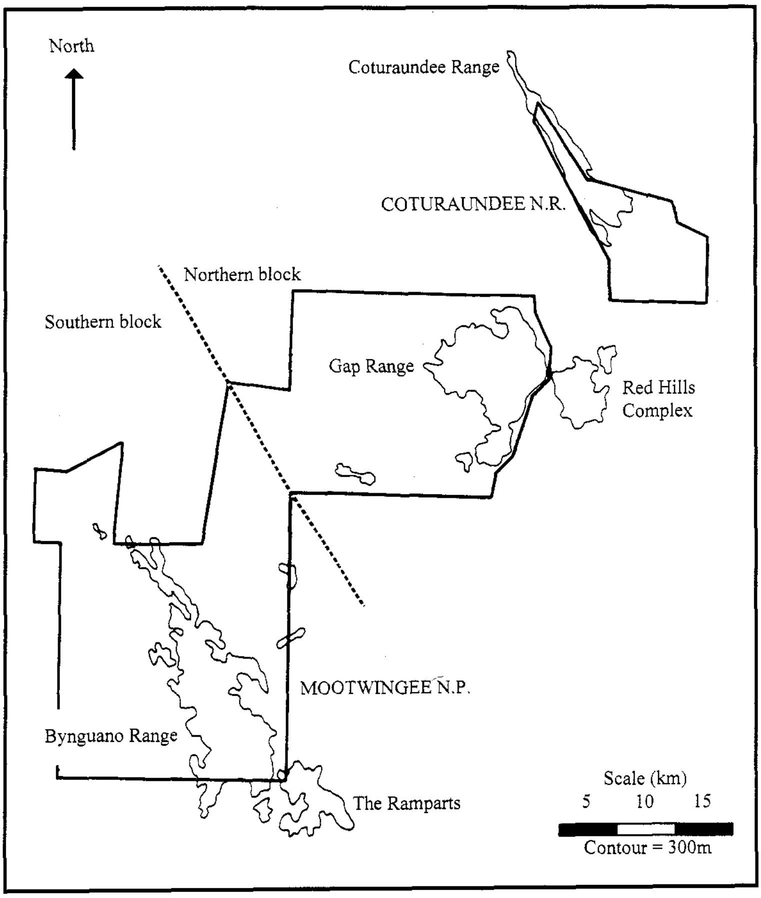

Fig. 1. The location of mountain ranges and the division of the two study blocks within Mootwingee National Park and Coturaundee Nature Reserve.

Between 1981 and 1997, the NSW NPWS removed feral goats from the reserves using both mustering (motorbike and helicopter) and aerial culling techniques. Prior to June 1987, opportunistic mustering was the primary goat removal method. Between July 1987 and June 1995 aerial culling was extensively utilised to remove large numbers of goats from the reserves. During this period, culling occurred several times per year, with the intervals between culling events being dependent on aircraft availability. After June 1995, a trial began using licensed musterers to remove goats from reserve areas and the provision of materials to neighbouring landholders for the construction of goat trap yards at watering points in paddocks adjoining the reserve estate.

Aerial culling was conducted from a Euro-copter Squirrel, using a self loading 7.62x59 mm rifle in open habitat and a semi-automatic 12 gauge shotgun in hilly habitat. Culling operations were undertaken by trained shooters in accordance with the guidelines laid down by the Australian Agricultural Council's Sub-committee on Animal Welfare (Anon. 1991). All kills were verified by the pilot and recorded by a third person.

For the majority of culling events undertaken between January 1988 and December 1995, the following data were recorded: number of goats shot, flying time and shooting location. These data were used to derive indices of goat population size for each culling event based on the number of kills per unit effort (see Parkes 1990. Hone 1990, Parkes *et al.* 1996). Indices were calculated as Ln(number of goats shot/minute flying time+1). Data were used in the calculation of the population indices only when both flying time and area were known. Travel time to and from culling areas was excluded from the calculation of flying time.

The use of 'number of goats shot/minute flying time' as an index of goat numbers was potentially open to influences of bias resulting from the culls being conducted opportunistically, rather than in a systematic fashion. For example, if large numbers of goats were found in one small area then effort was concentrated in culling them, often resulting in all available flying time being consumed without other areas being searched. Under such conditions the index could represent an over-estimate of goat density. Similarly, if goats were eradicated from one area during a culling operation and then effort was focused in another area on subsequent occasions, with large numbers of goats also being shot, the second index could feasibly be as high or higher than that associated with the initial cull. These conditions could result in possible decreases in goat density not being recorded.

In order to reduce the bias of concentrated effort within particular areas, the study site was divided into 2 blocks (North and South; see Fig. 1) and population indices were calculated separately for each block. The division of the study site into two blocks would have greatly reduced the influence of potential biases because most culling operations covered all areas within either the northern or southern blocks of the reserves (vagaries of the data recording system prevented the division of the study site into smaller sub-units). During culling operations, blocks were searched in an opportunistic fashion.

On several occasions goats were shot over areas that incorporated portions of both the northern and southern blocks without a delineation between the two areas being made on the data sheets; these data were ignored in the calculation of population indices. Unfortunately it was not possible to link the population indices to estimates of goat density because population surveys were not performed concurrently with the culling operations.

To determine the general response of the goat populations to the aerial culling program, linear regression equations (Zar 1984) were fitted to the population indices (plotted over time) and the slopes of the regression lines calculated. The slope of the line plotted through the population indices provided a measure of whether the populations were increasing, decreasing or stable over the study period (Caughley and Sinclair 1994).

Yellow-footed rock-wallaby numbers were monitored through annual helicopter surveys. These surveys were conducted over three consecutive mornings, during the winter months

(June-August), between the hours of 0700 and 1000. Between 1980 and 1985 the surveys followed the methodology outlined in Lim *et al.* (1992); i.e. an observer sat within the helicopter, and recorded wallaby sightings on a map of the area (data for 1980 to 1985 extracted from Lim *et al.* 1992). Between 1987 and 1991, the survey methodology changed to having two observers who sat on the floor of the helicopter with the doors removed and their feet rested on the skid. In 1992, the methodology was further refined with wallaby numbers recorded after the completion of each survey block (see Lim *et al.* 1992), rather than individually recorded on map sheets.

The mean number of wallabies seen by the front observer each year (days within surveys used as replicates; n=3) was used as an index of the wallaby population within the entire study area; i.e. the Gap and Coturaundee Range sub-populations combined. A one-way analysis of variance (Zar 1984) was used to assess any significant differences between wallaby numbers over the years of the intensive goat control program (1988-1995). It was anticipated that any positive responses in the wallaby population during the intensive culling period would arise following periods of above average rainfall, when forage resources would be more abundant, thereby resulting in increased levels of successful recruitment into the population. However, this response would only become apparent two years after the pulse of recruitment, because the probability of sighting juvenile wallabies (1 to 3 kg) during the aerial surveys was low. Rainfall data for the township of White Cliffs (30 km north-east of the Coturaundee Range) was used to calculate total rainfall between successive wallaby surveys and average rainfall was calculated over the period July to June (1970-1995).

Results

In total, 42,516 goats were removed from the reserve areas between January 1981 and September 1997 (13,089 mustered, 29,427 shot; Fig. 2). Prior to June 1987, 6058 goats were mustered and 1273 shot from a helicopter (Fig. 3). Between July 1987 and June 1995, 1081 goats were mustered and 28,154 shot (Fig. 3). After June 1995, 5950 goats were either mustered or trapped (Fig. 3).

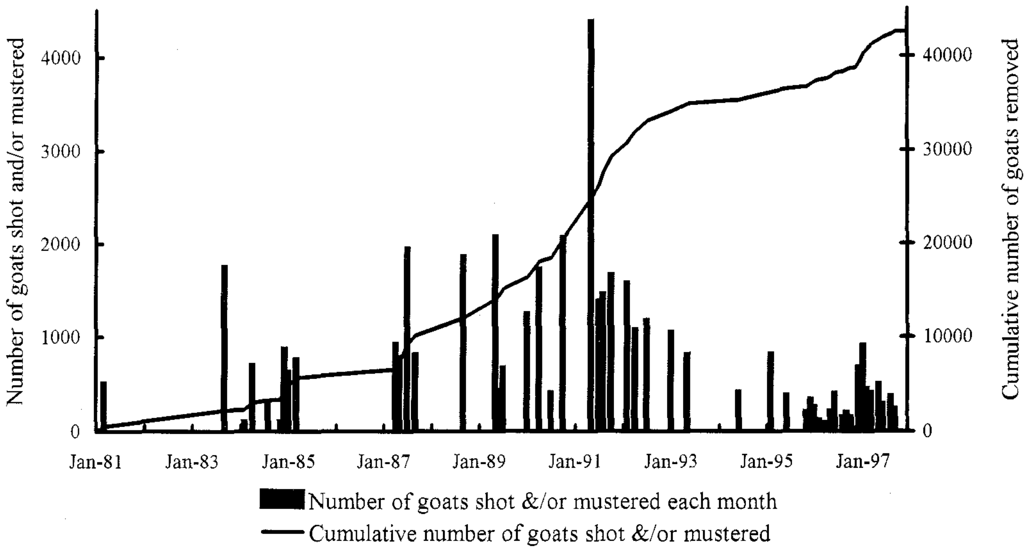

Fig. 2. The number of feral goats removed each month and the cumulative number of goats removed from Mootwingee National Park and Coturaundee Nature Reserve, between January 1981 and September 1997.

Sufficient data were available to calculate population indices for the majority of culling operations between January 1988 and June 1995 (see Table 1). The population indices for each

Table 1. The number of goats shot and flying time during helicopter culls on Mootwingee National Park and Coturaundee Nature Reserve, between September 1988 and June 1995.

	Northern block		Southern block		Undefined areas		
Culling period	Number of goats shot	Flying time (mins)	Number of goats shot	Flying time (mins)	Number of goats shot	Flying time (mins)	Total for culling period
Sep-88	319	163	850	458	*167**	*90*	
“ ”	---	---	*221*	*?*	*138*$^{\#}$	*73*	
“ ”	---	---	---	---	*161*$^{\#}$	*?*	1856
May-89	1073	435	673	220	---	---	1746
Jun-89	169	120	---	---	*256**	*175*	425
Jul-89	467	230	---	---	*196**	*75*	663
Jan-90	429	358	560	388	*248**	*70*	1237
Apr-90	149	115	878	489	*431**	*201*	
“ ”	---	---	---	---	*64*$^{\#}$	*80*	
“ ”	---	---	---	---	*191*$^{\#}$	*?*	1713
Jul-90	301	132	102	40	---	---	403
Oct-90	949	325	824	530	*283**	203	2056
May-91	3013	1395	1164	459	*190**	*66*	4367
Jul-91	772	245	55	120	*251*$^{\#}$	*90*	
“ ”	---	---	---	---	*296*$^{\#}$	*?*	1374
Aug-91	935	261	511	204	---	---	1446
Oct-91	546	243	739	372	*275**	*105*	
“ ”	---	---	---	---	*93*$^{\#}$	*60*	1653
Feb-92	---	---	*1567*	*?*	---	---	1567
Apr-92	759	505	309	180	---	---	1068
Jul-92	671	372	321	208	*103**	*130*	
“ ”	---	---	---	---	*70*$^{\#}$	*56*	1165
Jan-93	393	170	115	91	*384**	*170*	892
May-93	---	---	296	113	*154**	*124*	
“ ”	---	---	---	---	*354*$^{\#}$	*142*	804
Feb-95	235	335	574	296	---	---	809
Jun-95	96	120	276	120	---	---	372
Mustered	325	---	---	---	---	---	325
Total goats removed	11 601		10 035		4 305		25 941

Data in italics were not used in the calculation of population indices (* = cull data that could not be used because the division between northern and southern blocks of the study site could not be discerned from the data sheets; # = the areas over which aerial culling occurred was not recorded on data sheets; ? = flying time during aerial culling was not recorded).

block of the study site are contained in Figs 4 and 5. It can be seen from these data that the impact of culling on the goat population was often short-term, with indices of goat densities frequently returning to pre-cull levels, or higher, by the time of the next culling event. This was particularly evident for the May 1991 cull in the northern block, when 3013 goats were culled. Within two months of this event the population index indicates that the density of goats was higher than that during May 1991 (Fig. 4a, Table 1). On occasions when large numbers of goats were culled, the index of goat density generally increased to pre-cull levels within 3 to 12 months, despite additional culls often being conducted in the interim.

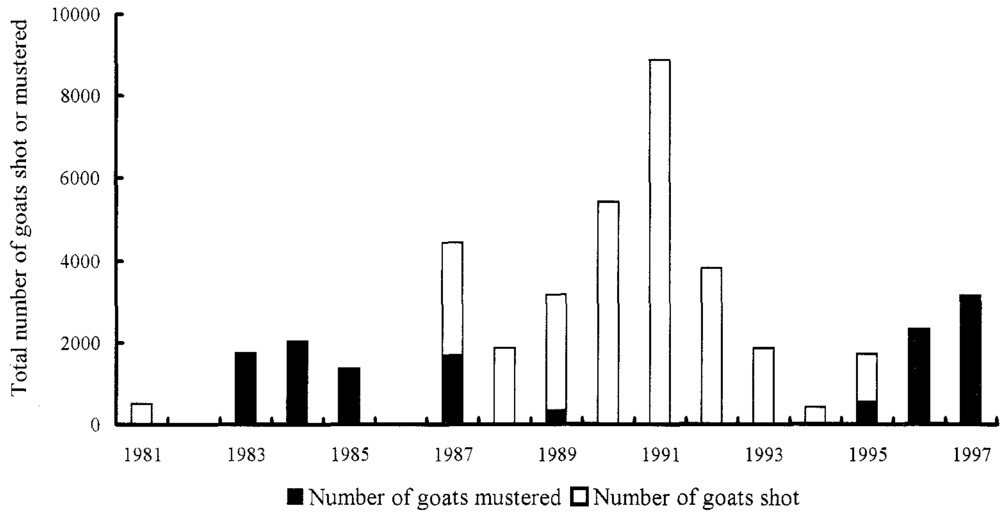

Fig. 3. The number of goats shot and the number of goats mustered each year from Mootwingee National Park and Coturaundee Nature Reserve, between 1981 and September 1997.

The long-term trends in the population index can be seen in Fig. 4. Though the slopes of both regression lines were negative, they were both close to zero (northern -0.005, R^2=0.170, P>0.05; southern -0.0003, R^2=0.001, P>0.05; Figs 4a and 4b). This suggests that goat numbers did not appreciably decline in either area over the January 1988 to June 1995 period despite the removal of 25,941 goats from the reserves (11,276, northern; 10,035 southern; 4305, other areas; 325, mustered; see Table 1).

The mean number of yellow-footed rock-wallabies counted by the front observer can be seen in Fig. 5; no survey was conducted in 1986 and data from the front observer were not retrievable for the years 1987, 1990 and 1991. Wallaby numbers can be seen to decline markedly in 1983, as a result of a severe drought during 1982 (Lim *et al.* 1992), and then return to comparable pre-drought levels by 1985. During the period of the intensive goat culling operations, 1988 to 1995, wallaby numbers declined and then remained at low levels.

The results of the one-way ANOVA (see Fig. 5) indicate that wallaby numbers in 1989 were significantly higher (P<0.01) than in either 1988, 1992, 1993, 1994 or 1995. In addition, wallaby numbers during 1993, 1994 and 1995 were significantly lower (P<0.01) than during 1988. The noted increase in 1989 suggests that there was a pulse of successful recruitment into the wallaby population between July 1986 to June 1988 (Fig. 5). During this period, 4429 goats were removed from the northern block of the study area and a favourable rainfall pattern was noted (301 mm, 1986-1987; 389 mm 1987-1988; Fig. 5). However, this pattern was not repeated following the above average rainfalls (616 mm) during the period between the surveys of 1992 and 1993, with no increase noted in wallaby numbers during either 1994 or 1995 (Fig. 5) despite the removal of 3304 goats from the northern block (August 1991 to June 1993).

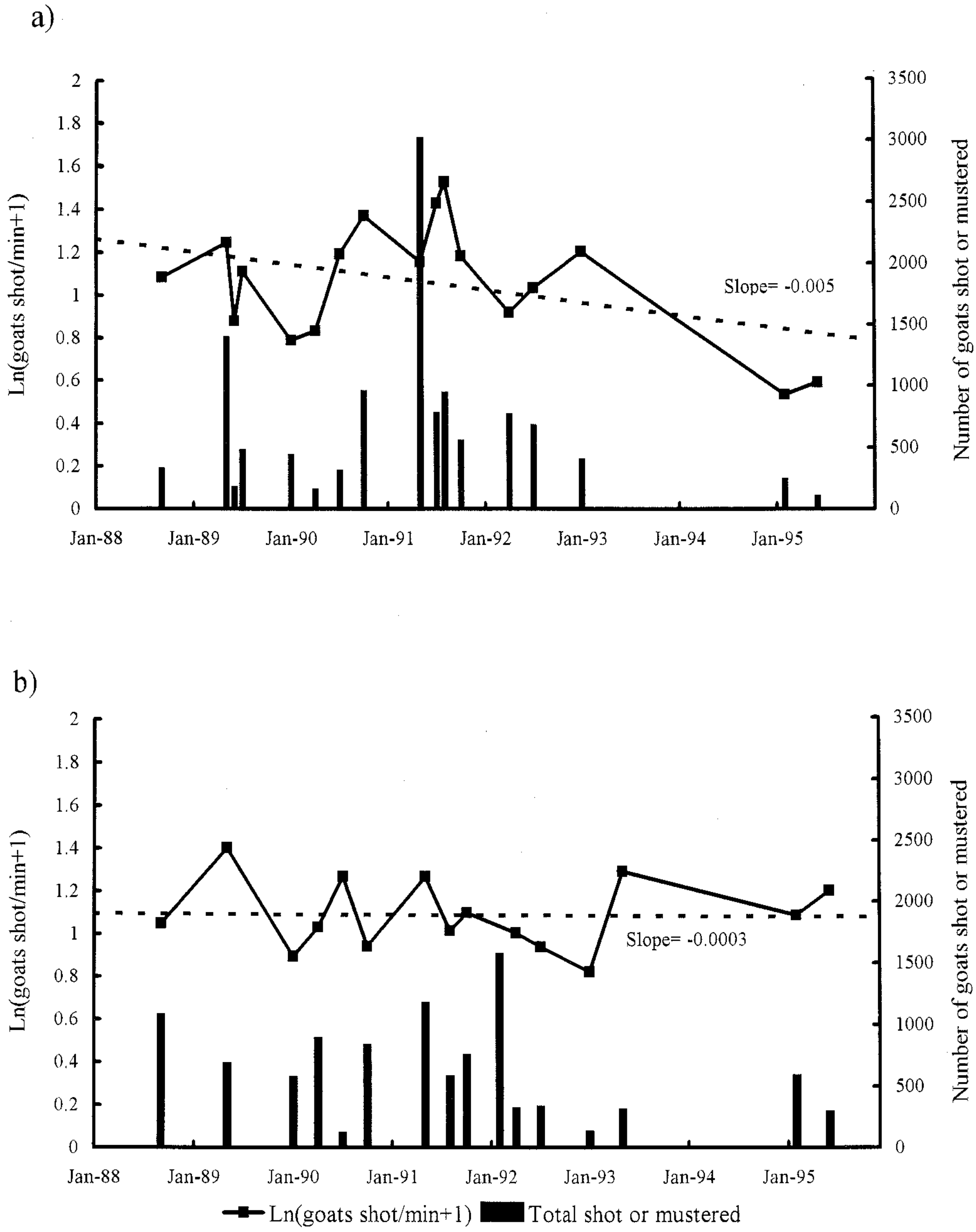

Fig. 4. Population indices (ln(goats shot/min+1)) of feral goats and number of goats removed across; a) the northern block of the Mootwingee National Park and Coturaundee Nature Reserve study site and from b) the southern block of the Mootwingee National Park and Coturaundee Nature Reserve study site, between January 1988 and June 1995. Hatched line represents the linear regression line of best fit through the population indices.

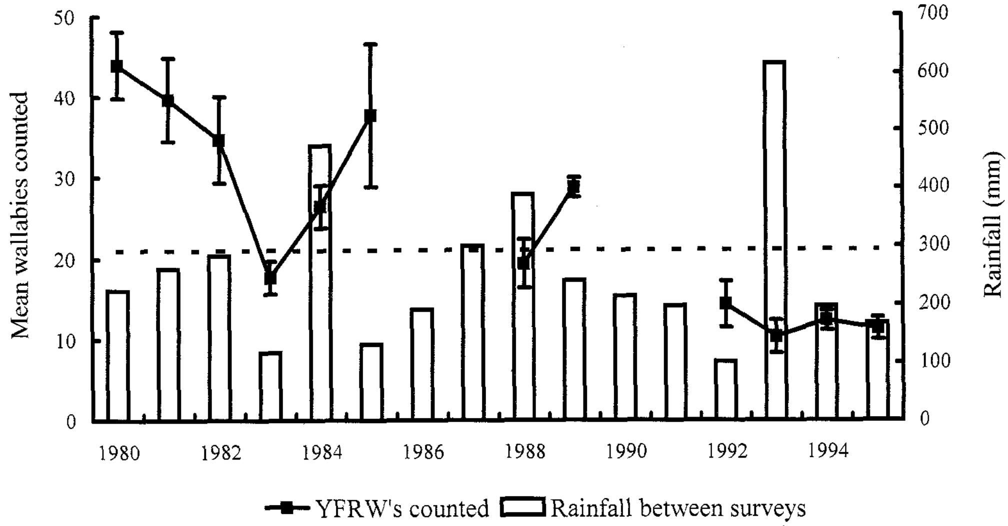

Fig. 5. The mean number of yellow-footed rock-wallabies counted during helicopter surveys of the Mootwingee N.P.-Coturaundee N.R. population (1980 to 1995; standard error bars shown) compared with total rainfall noted in the period between the current and previous surveys. Hatched line represents average annual rainfall between July and June (calculated from data for 1970 to 1995).

Discussion

The 'kill/unit effort' index may not have been sensitive to changes in goat density. A curvilinear relationship is predicted between actual density and 'catch/unit effort' indices (Caughley 1977). Under such conditions, a density threshold exists beyond which catch/unit effort will become constant. The existence of this threshold limits the accuracy of the index, if the threshold is reached. Pople (pers. comm.) suggested that in the case of aerial goat culling this threshold exists within the range of 1-2 goats/km^2, resulting in a maximum of 60-100 goats shot/hour (based on the evaluation of cost per kill data in Pople *et al.* 1996). Translating this data into the index used in the current study, produces indices of 0.7 and 1.0 (respectively).

If a similar relationship holds for this study, then the noted fluctuations in the indices would not accurately reflect changes in actual population densities; i.e. actual densities were consistently higher than 1-2 goats/km^2 and therefore the indices were insensitive to changes in population size. However, in this study 93.75% of the calculated indices had values higher than 0.7 (i.e. 60 goats shot/hour) and 65.63% were higher than 1.0 (i.e. 100 goats shot/hour; range=28 to 215 goats shot/hour). This suggests that the maximum threshold within the Mootwingee N.P.-Coturaundee N.R. study site may be higher than that noted in the study of Pople *et al.* (1996). This may have resulted from the more open nature of the habitat and/or differing skill levels of both pilots and shooters. Without data on actual goat densities, it was impossible to evaluate the value of the threshold in this study. However, if the maximum threshold does indeed reside in the vicinity of 2 goats/km^2, then this would indicate that goat density was rarely reduced below this level despite removal of large numbers of goats.

None the less, the 'kill/unit effort' indices did provide some insights into the dynamics of goat numbers over the course of this study. The results of this study indicate that goat numbers were not effectively reduced on the reserve areas despite the intensive aerial culling program (1988-1995). The impact of culling was generally short-term and often negligible. Annual rates of increase in goat populations have been documented at relatively high levels (Parkes *et al.* 1996), including 42% for a population in western NSW (Mahood 1985). However, given the removal of large numbers of goats and the short period of time between culling operations (mean=4.12 months, SE=0.62, north; mean=3.89 months, SE=0.59, south), it is highly improbable that the rapid increases in goat density were attributable to births from within the remaining post-cull population. This suggests that the impact of culling was rapidly offset by a high level of immigration by goats from areas adjacent to the study site.

Similar results and conclusions were found by Pople *et al.* (1996) who conducted a more detailed goat removal experiment within the mulga lands of central-western Queensland. They monitored goat numbers before and after control activities at a number of locations, using aerial surveys. At a high density site (Ravensbourne; 14.5 goats/km^2) the goat population was found to have returned to numbers close to that of pre-control levels within 6 months (4647 and 3654 goats respectively), despite the removal of 4699 goats. High levels of immigration were proposed to account for the rapid recovery of the goat population on this site. In contrast, Maas (1997) found that culling operations at Mount Gunderbooka (central NSW) effectively reduced goat densities from 9.6 goats/km^2 to 3.1 goats/km^2. Over a 24 month period following the control operation, goat densities did not increase above the level expected from natural recruitment from within the remaining population (5.6 goats/km^2).

In the semi-arid and arid zones, goats show a preference for mountainous, rocky areas which provide abundant shelter from the extremes of temperature (Mahood 1985). As the boundaries of Mootwingee N.P. and Coturaundee N.R. encompass the majority of the range systems within the local area (i.e. the Bynguano, Gap and Coturaundee Ranges), the removal of goats from this area would have created a sink into which goats from outside areas quickly moved. This movement into the study area would therefore have followed a gradient of both decreasing goat density and increasing habitat quality.

The shift in focus from culling to live removal in 1995 occurred as a result of the high cost of aerial shooting and substantial increases in the market price of live goats. The use of a licensed musterer and the provision of trap yards to neighbouring landholders proved to be an effective method of removing goats. Once past the initial set-up phase (July 1995-December 1995), mustering and trapping removed comparable numbers of goats (n=2307, 1996; n=3116 January-September 1997) to the aerial culling program (annual mean=3468.6, SE=928.2, 1987-1994). However, while mustering and trapping were successful at removing large numbers of goats, there were insufficient data to evaluate the overall effectiveness of these techniques at reducing goat densities on the reserves. Edwards *et al.* (1997) documented a significant reduction in goat densities as a result of a combined mustering-aerial culling program (2387 mustered, 663 shot), in the mulga woodlands of south-western Queensland. These authors concluded that mustering was effective at reducing goat numbers at high densities and that further reductions could be achieved through follow-up aerial culling.

An additional advantage of the mustering and trapping program was that goats were removed immediately following their detection rather than removal occurring on a seasonal basis (i.e. aerial culling). This would have acted to reduce the overall impact of grazing and other deleterious activities. However, the future success of this approach will be primarily dependent on the willingness of musterers and landholders to undertake control activities, which in turn will be driven by the vagaries of the live goat market.

The inability of the intensive control program to counteract the high levels of immigration into the reserve areas highlights the need to conduct goat control measures over a broad geographic base, particularly in areas of high goat density. The removal of goats from relatively small areas, such as Mootwingee N.P. and Coturaundee N.R., creates a sink into which goats from adjoining areas may quickly move into. Hence, the effective control of goat numbers on individual conservation areas or pastoral properties will require the control of goats on neighbouring properties (Holt and Pickles 1996, Edwards *et al.* 1997). The scale at which control programs are conducted will not only determine the success of the programs, but will also introduce an economy of scale and thereby reduce the cost of control to individual properties. In addition, the size of feral goat home ranges (see King 1992, Holt and Pickles 1996) suggests that they are likely to overlay portions of several adjacent pastoral-conservation properties. If control programs are limited to one property then goats may escape removal by virtue of being in a portion of their home range that is inaccessible to the control activity at the time it is undertaken.

If the target goat population exists within a landscape of high goat density, the impact of any culling operations may be quickly negated by immigration from adjacent areas. This is highlighted in the conflicting results of this study and those of Pople *et al.* (1996; density=14.5/km^2) and Maas (1997; density=9.6/km^2). A study conducted by Holt and Pickles (1996) to examine goat movement at a site adjacent to a culling area found no movement of goats and no change in home range size between pre- and post-cull conditions. However, this study did not provide any measure of goat densities in the adjacent areas. The extent to which goat population dynamics within control areas are influenced by immigration from adjacent populations and the role that goat density plays in this process should be evaluated through a radio-telemetry study of individuals from adjacent populations, pre- and post-culling.

The diets of goats and yellow-footed rock-wallabies within the study area have been noted to exhibit considerable overlap (Dawson and Ellis 1979), ranging from 41% in good seasons to 75% during periods of drought. It is highly likely that competition for food resources during periods of scarcity may significantly impact on wallaby numbers (Lim *et al.* 1992); e.g. the documented drought of 1982 (see Fig. 5). However, because the impact of the goat population on the vegetation of the study area was not monitored, it was impossible to definitively comment on the levels of competition that existed between the two species during the study period.

The lack of response in the wallaby numbers (between 1988 and 1995) could result from i) the level of control being insufficient to reduce goat numbers to levels where competition for food resources was lessened and the wallaby population could increase, ii) the goat control may have significantly reduced goat numbers, but for only a short duration between culling events or iii) competition between goats and the wallabies was not the limiting factor keeping the wallaby numbers low. Given that the control operations removed large numbers of goats between 1988 and 1995 (25,941 goats; Table 1) and that they generally occurred on a seasonal basis, it is unlikely that the removal exercise did not reduce to some extent the competitive interactions between these two species, except during periods of resource scarcity (i.e. drought). In addition, the extent to which the species are likely to compete is unknown as the goats are generally only found within the wallabies foraging areas for short periods when they are moving into and away from the range country at dawn and dusk, respectively (Sharp, pers. obs.). Though competitive interactions with goats, for food resources, are likely to have a negative impact on the wallaby population, there is no evidence that this relationship was the primary factor limiting the wallaby population during the period of this study.

This study suffered from two major limitations which should be addressed by all future goat removal experiments. The first was the lack of direct data on goat densities, which would have allowed for a more accurate assessment of the dynamics of the target population (see Pople *et al.* 1996, Maas 1997, Edwards *et al.* 1997). The second limitation was the lack of any intensive assessment of the impact of damage by the goat population; i.e. in this study, the impact on vegetation dynamics and/or changes in the levels of damage to Aboriginal art. Likewise, little could be inferred on the impact on yellow-footed rock-wallaby numbers due to the lack of data on vegetation dynamics.

The noted indices of goat population size suggested that goat numbers were not effectively reduced over the long-term, however, the short term removal of goats may have been sufficient to mitigate the damage incurred by goats. However, without specific data on the suspected impacts of the goat population it is impossible to evaluate whether this exercise effectively reduced goat damage or merely functioned as a sustained-yield harvesting program (Caughley and Sinclair 1994).

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