

# **Improving NRM Outcomes in the Rangelands by Strategically Removing Feral Goats**

**An interim report on the evaluation of ecological indicators to be used in monitoring and  
evaluation frameworks for appraising impacts of feral goat on native vegetation and the  
effectiveness of feral goat control treatments**

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## Summary

The SAAL NRM Board has recently adopted a policy of reduction in feral goat populations within its District. Integrated feral goat control treatments including an aerial cull, were conducted on 20 properties over April and March 2009. Three properties were selected for ecological survey to evaluate effectiveness of the control treatments and to assist development of monitoring and evaluation framework for appraising feral goat impacts.

Ecological surveys were carried out in the period 27 July to 3 August 2008 over 3 properties of semi-arid rocky ranges and hills where the complex interactions of multiple large herbivores could be minimised, especially that of dietary overlap. Observed browse impacts could be largely attributed to feral goats. Properties included Pitcairn Station, Yadlamalka Station and Yardea Station, which possess similar vegetation characteristics, though in different ranges systems.

Ecological survey was conducted too soon after controls to conclude that treatments had been successful, but preliminary observations reported here are consistent with a successful program. Observations and measures made, have clearly identified a suite of plant indicator species, the parameters to measure and the means of analysis for a Monitoring and Evaluation Framework not only for single episodes of intensive control treatments, but also for ongoing control.

A comprehensive monitoring framework could be developed which would rigorously report on feral goat impacts on native vegetation, as well as be suitably adapted for property owners to gauge impacts within their own localities. Targets and objectives over short, medium and long terms readily stem from measures being made and potentially serve an adaptive management process, where observations may indicate maintaining existing control programs or prompt alterations to them.

This survey concentrated solely on semi-arid rocky ranges, but is based on a framework being developed for arid rocky ranges in the proposed Bimbowrie Conservation Park. A different suite of plant species indicators is used there, but parameter measures are identical and some of species indicators occur in both arid and semi-arid ranges.

## Introduction and Background

The South Australian Arid Lands Natural Resources Management Board formalised feral goat management policy in November 2008. Seeking reduction in feral goat populations as its principle objective, the Board invited participation from property holders in an initial feral goat control project, culminating in combined aerial cull, trapping and mustering activity in April and May 2009. Control activities were undertaken in three regions – the Gawler Ranges, Flinders Ranges and western Olary Ranges, in arid and semi-arid environments.

Monitoring and evaluation phase of the project included an ecological component, which would primarily evaluate the most useful indicators and measures to appraise feral goat impacts and the success (or otherwise) of feral goat controls undertaken, leading to development of feral goat impact monitoring practices. CSIRO undertook general evaluation of ecological monitoring and evaluation practices with respect to feral goats in South Australia (Smyth et al, 2009), identifying principle issues of indicators for population numbers or density and for feral goat impact, including discussion on the general qualities and characteristics of useful indicators.

Field surveys were conducted in July and August 2009 on at least one property in each of the regions. These surveys attempted to evaluate the success of feral goat control activities as well as identify the most practical ecological indicators to use and the procedures for data collection, analysis and interpretation.

Limited project time severely restricts ecological monitoring and evaluation. Only high ranges properties in the semi-arid areas were evaluated. More importantly, field surveys concentrated on indicators of feral goat impact, rather than comprehensive procedures. Ideally, control programs would include population density surveys before and after implementation of control activities and impacts be evaluated some 6-12 months after controls, rather than immediately after. Impacts should be interpreted in relation to population density changes and total grazing pressure.

Field surveys assumed that significant reduction to feral goat density should realise a significant reduction in feral goat browsing pressure. In turn, this should be reflected in growth of the species subject to browse, under suitable seasonal conditions. Though somewhat drier in the western Olary Ranges, each of the three regions has had sufficient rain to induce growth responses. Field surveys then, concentrated on which browsed plant species should be the best species indicators and what plant attribute is best measured as the growth indicator.

Theoretical basis to this herbivore-plant response model is outlined in Keigley (1997, 2002a,b), which aims at management of native large herbivore populations in North America, through evaluating their impact on vegetation. This approach underlies the monitoring of landscape recovery in the hills of the proposed Bimbowrie Conservation Park. Feral goats are identified as the principal disturbance agent there and numbers have been intensively controlled since 2005. The monitoring and evaluation program for feral goat activity includes long-term ecological objectives and measures used to demonstrate recovery from previous excessive goat density as well as shorter term ecological objectives and measures that can evaluate ongoing control activities.

Survey results to date are consistent with successful feral goat control treatments, if not able to demonstrate it conclusively. More importantly, surveys showed that quality plant species indicators

are readily locatable and suitable attributes easily measured and analysed to evaluate impact or goat management objectives over the short or long term. Using these indicators, procedures can be devised, which accurately assess for scientific purposes, the extent and intensity of feral goat impacts. More simple, but compatible procedures, can be used by property owners to evaluate feral goat impacts on their land-holdings or localities.

### Properties Surveyed

Within project time frame, not all properties participating in the program could be suitably appraised, only three or four properties, which suggested at least one in each region. The need for reconnaissance trips to select sites for later survey, meant proximity to Adelaide, would influence choice. Properties with sizeable feral goat numbers, which were substantially reduced were also preferred, as these would likely reveal a more substantial growth response of browsed plant species.

Total grazing pressure influenced property choice substantially. To reduce dietary overlap with other native and exotic large herbivores, properties with high rocky ranges of rather open scrub (tall shrubland to low mallee) or hummock grassland were preferred, as these would have only feral goats and euro (*Macropus robustus*) as the sole large herbivores. *Macropus robustus* diets are restricted mainly to graminoid species except in the most dire of seasons, so any browse on shrub species, would be attributed to feral goats only.

In the absence of feral goat density surveys, the cull/removal tallies provide the best indication of population reduction. In consultation with Peter Watkins (Aerial Cull Supervisor), Pitcairn, Yadlamalka and Yardea Stations were initially selected. Reconnaissance trips showed these to be suitable in having relative accessible high ranges and numerous perennial plants browsed by goats. Potential for sheep impact could be discounted. Sheep have not been kept generally on Pitcairn Station since 2004. They are excluded from the high ranges paddocks on Yadlamalka (and according to manager, never found on the high hills). Surveyed portions of Yardea Station, were either being spelled from stock or were distant from water points. Using helicopter track logs, zones of more intense culling could be discerned for each property and reconnaissance trips were conducted inside these zones or on their margins.

Table 1 indicates brevity of period between treatment and survey. Pitcairn Station had little rain before treatments, so plant responses there have occurred between rainfall and survey, whereas on the other two stations rainfall prior to treatment stimulated some growth on plants prior to the cull.

Property	Aerial Cull	Survey	Period for Response
Pitcairn	13 May	27-28 July	74 days
Yadlamalka	4-8 May	30-31 July	82 days
Yardea	16-19 May	2-3 August	74 days

Table 1: Time periods for each property in which vegetation can show a response to control treatments

## **Site Selection**

Midslopes and crests of rocky hills and ranges with substantial outcrop and steep inclines, were principal areas surveyed. Reconnaissance trips revealed locations of perennial plant species browsed by feral goats, with presence of abundant goat dung and hoof prints further identifying the main browser. Species preferred by feral goats, even if not widespread, commonly occurred throughout the properties in sufficient presence for measures to be made.

Studies on the home ranges of feral goats provided some indication of distances to separate survey sites. King 1992, Holt et al 1996 and Freudenberg et al 1999 consistently show that home ranges as expressed by the general movement of females are of the order of 4-6 km x 4-6 km. Males are more mobile and capable of moving through home ranges 6-9 km x 5-8 km. Furthermore they show that there is some fidelity of mixed sex groups to a home range, but longer study of Freudenberg et al suggested some males may circulate through a few home ranges of otherwise separate groups. This suggested that by separating sites by at least 4 km and with a series of sites spanning distances exceeding 12 km, observed impacts most likely relate to different social groups. Such distances, topographic and surface characteristics as well as accessibility, basically determined the location of reconnaissance walks; the presence of sufficient preferred and browsed species, then fixed a survey site more precisely.

## **Plant Species Indicators**

Goats are generalist herbivores that at any time, will feed on foliage, bark and twigs of tree, shrub and forb species. Sheep are more selective herbivores, preferring grass and herbage and shifting generally to tree, shrub and forb species, as onset of dry seasons, desiccates more succulent groundcovers. Perennial woody plant species eaten by sheep, will usually be the same species that goats prefer, allowing for differences in habitat. Perennial chenopods, the mainstay of the "haystack" of plains and rolling low hills in the sheep industry are also targeted by feral goats in the higher, more rugged hills, though different plant species are involved.

Any plant species that is browsed by goats and whose response to intensified or relaxed browsing is measurable will be a useful indicator. Some species can be more useful than others because inferences may be made about the degree of impact feral goats have had over the longer term. Herbivores exhibit preferences for the more palatable of plant species and the more these species are eliminated from ecosystems, the greater the degree of disturbance to that community. Conversely, the presence of the most favoured species and particularly, their healthy regrowth after effective controls are implemented, are signs of satisfactory recovery and minor degradation.

Lists of perennial plant species observed to be browsed, and where feral goats clearly present, were compiled during reconnaissance and survey.

## **Species Population Sampling**

Population sizes and density of the indicator plant species are variable. Ideally populations are appropriately sampled to derive characteristics representative of them eg stratified random sampling. Variability in patch size and number precluded employment of random sampling procedure, within time allotted to survey. Individuals were arbitrarily selected for the apparent variation in measures they offered.

## Browse Impacts and Measures

Feral goats can only browse as much as their physical capability permits – in short, only as far as they reach, which is limited by their ability to stand steady on their hind legs. This generates two primary forms of plants that are constantly or intensely browsed. Those plants which can never grow beyond the reach of goats (low shrub and shrub species), are constantly browsed or “hedged” and plant size is always below optimum dimensions. Those plants beyond goat reach (very tall shrub and tree species) develop a browse line of constantly maintained height, while their regenerating forms are kept small, until they manage to eventually exceed maximum goat reach.

All shrubs and trees grow to improve their photosynthetic capture. The browsing of growing shoots, decline of those shoots and later re-emergence when conditions improve is described by Keigley (1997) in “architectural” form stages. Somewhat adapted for feral goat impact and illustrated accordingly these form stages are:

*Uninterrupted*: fresh green shoots, largely unaffected by browsers and extending episodically in relation to growth stimuli; may include very light browse pressure of growing tips

*Arrested*: hedging or topiarised forms subsequent to intense browsing (see figures 1, 2 and 3), where new shoots, usually also browsed, do not extend past the browse levels of previous times

*Retrogressed*: death of all or some stems previously browsed and new growth emerging from lower stems; stem death arises from stresses induced by browse (see figure 4)

*Released*: new shoots emerge from browsed stock but are not browsed due to temporary or permanent relaxation of browse pressure (see figures 5, 6)

Keigley (1997) applied these form stages within an age-classing of plant individuals, relating them to browsing time sequence and listed various methods to quantify amounts of growth lost through browsing or gained through growth. Condition evaluations could be made, based on forms exhibited by preferred and non-preferred plant species present at a site.

Keigley et al (2002a,b) expands these notions to landscape level evaluations of ungulate browse, designed to appraise seasonal impacts of large native herbivores on native vegetation in the United States. Browse forms cycle through each stage yearly, with *Released* form being the foundation for *Uninterrupted* form of a following year. In this context, the shrub and tree species are adapted to browse, from large herbivores such as elk, deer, moose and antelope. Australian native shrub and tree vegetation, in general, is not evolutionarily adapted to current large herbivore populations. Furthermore in Australian vegetation, *Released* forms appear after sufficient rainfall provides a stimulus for growth; it will not occur annually as in the situations Keigley examines. This does not influence the measures which may be made, simply the times when measures take place.

With successful feral goat controls, *Arrested* and *Retrogressed* forms should not re-appear. Reduced browsing pressure should result in growth of the browsed shrubs and tree regeneration that continues upward and outward. In the short-term, measures of the growth from *Arrested* form to the *Released* form would be a measure of reduction in browsing pressure.

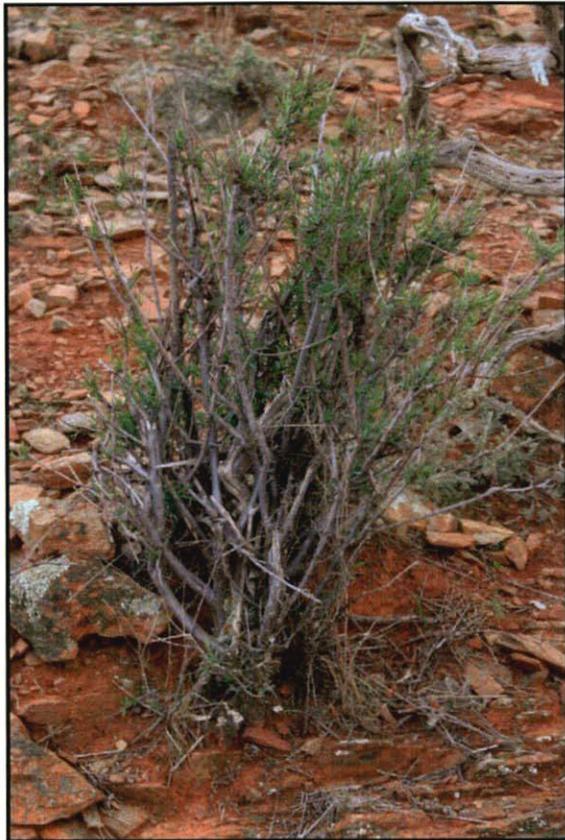


Figure 1: *Pimelea microcephala* in Arrested form with new shoots of very short length emerging from browsed stems



Figure 2: *Prostanthera striatiflora* in Arrested form; new shoots extend above the browse perimeter and mark transition to Released form. Tallest parts of the browse form and the new growth are readily identifiable and measurable.

Figure 3: Heavily Arrested form of *Eremophila oppositifolia*; new shoots are protected from browse by rigid stems and plant may have been kept in Arrested form for many years



Figure 4: Extremely Retrogressed form of *Eremophila alternifolia*; new growth only emerges at the base of the main trunk

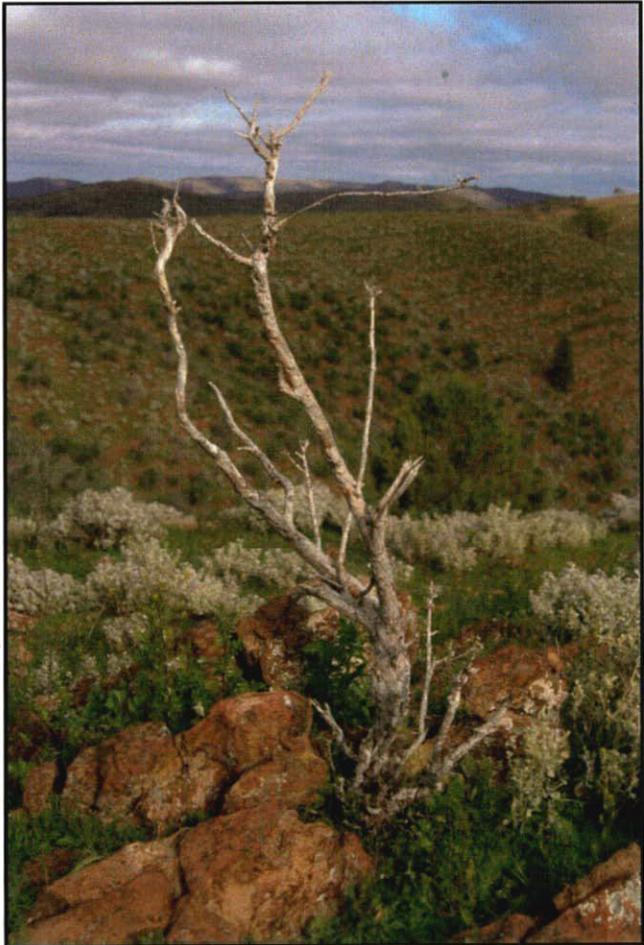




Figure 5: *Prostanthera striatiflora* bush abundantly sprouting and advancing to Released form

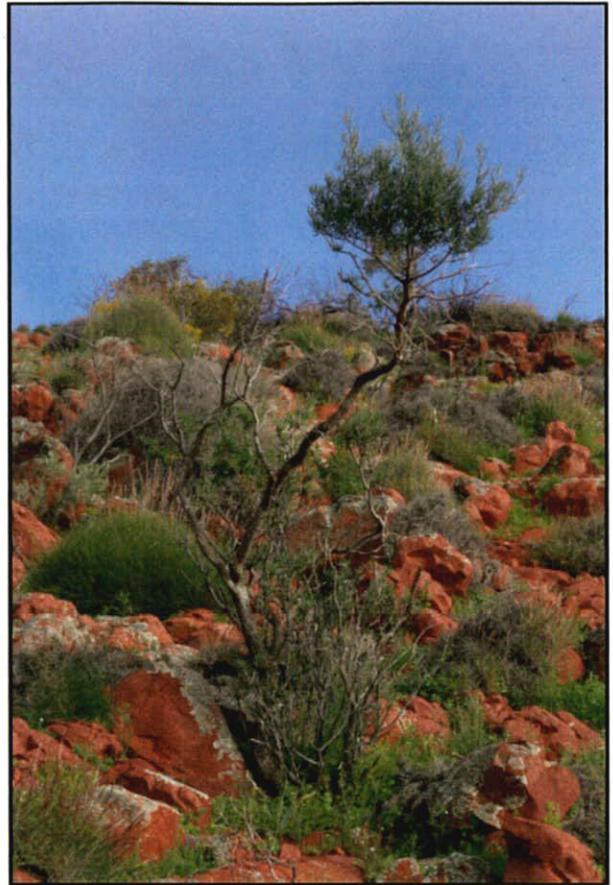


Figure 6: *Eremophila alternifolia* once in a Released form, which exceeded feral goat browse height. Currently in Arrested form (below the browseline), the bush is at risk of Retgression should intense browse pressure remove the foliage and induce stem death.

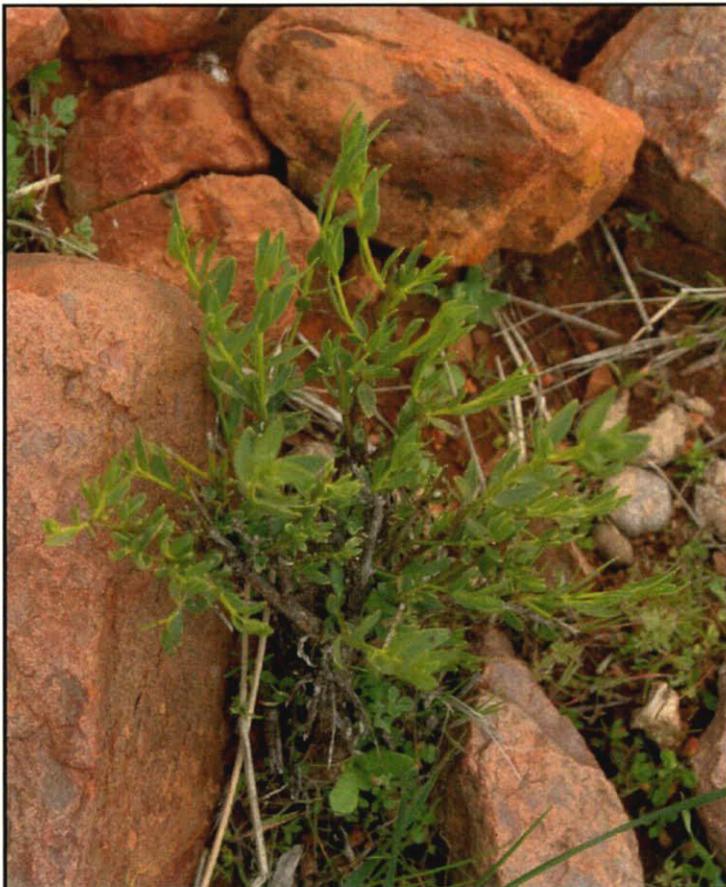


Figure 7: In this *Prostanthera striatiflora*, the browse form (Arrested stage) is visibly defined in height, length and width by stubby grey, slightly fibrous, broken stems the thickness of drinking straws. New growth extends beyond browse form and is characterised by smooth, green-yellow shoots as thick as toothpicks with reddish-green bases as thick as matchsticks.

From such responses, quantitative measures more simple than those listed by Keigley (which are mainly biomass measures) can be employed. The ultimate objective for plant growth is attainment of the mature dimensions of the plant species concerned. Tree species become tree forms and shrub species fill out. Such targets become the aim of longer term evaluations ie of maintained low populations of feral goats. Any return to observed stages of *Arrested* and *Retrogressed* forms, means the goats have returned to their problem densities. However, the onset of *Arrested* forms also becomes the trigger to implement goat control in an adaptive management framework.

Tree species are characterised by a single trunk and relatively greater height compared to lateral dimensions. Tall shrubs though multi-stemmed, also possess significant height component, and like trees, their chief tendency is upward growth. Low shrubs have variable dimensions, but many are compact with comparable height, length and width; their chief tendency is simply to grow outward. The simplest measures then would be heights of tall shrub and tree species and height, length and width of shrub and low shrub species. This works well with feral goats as generally their upper browse limit is about 2m, the height which separates shrubs from tall shrubs.

Form stages described by Keigley can be preserved in the field over a number of seasons. Such preservation became a baseline for monitoring in (proposed) Bimbowrie Conservation Park. First extensive goat controls there were undertaken in March 2005 and repeated in March 2006. Seasons remained dry until late June 2006. Visits in September 2006, revealed *Acacia aneura* regeneration in newly *Released* forms, but woody stumps (below 50 cm height) of resembling *Arrested* and *Retrogressed* forms persisted, identifiable in stubby appearance of short non-living twigs and stems with diameters from 2 to 25 mm.

Short-term measures then simply are a comparison of the dimensions of the *Released* form, with that of the *Arrested* or *Retrogressed* forms. For the mulga on Bimbowrie, the varied diameters of browsed stems from the most recent shoots (about 2 mm) to older browsed stems (about 5 mm and 10 mm), indicates the bushes have probably been maintained in an *Arrested* form for at least a few years, temporarily enjoying *Release* before being browsed again. As largest dimensions of the *Arrested* form (height, length, width) are still much less than those of a mature plant, these dimensions become a baseline against which later growth can be progressively compared. If dimensions of growing plant exceed the baseline and continue to increase then feral goat numbers have been reduced and populations are maintained at low levels. If difference in dimensions exceed the baseline initially, but then become comparable, initial feral goat controls were effective, but goat numbers have gradually increased to problematic levels of previous times.

On proposed Bimbowrie Conservation Park, individual plants are permanently marked and repeated measures of the same plants are the principal means of evaluation of growth especially in relation to the past browse baselines. The focus is on tree species (*Acacia aneura*) and tall shrub species (*A. tetragonophylla*, *Eremophila alternifolia*) so the principal measure of interest is the height of progressively growing *Released* form, in relation to its *Arrested* form baseline height as measured in 2007 or 2008 (when the monitoring scheme was implemented). For other ecosystems however, low shrub species are strongly targeted by goats, so in the ecological survey for this project, the plant dimensions of height, length and width were measured.

## Impact Measure Procedures

Height, length and width are very simply measured. Where thickest stem enters the ground is the basal reference for height measures. Vertical measures to the plane of the highest part of the browsed form and highest new shoot are the height measures (see figures 2 and 7). Length is a lateral measurement of the longest dimension that separates any two parts of the browse form or any two fresh shoots of new growth. Axes of length of browsed form and new growth form are often coincident (or nearly so) but need not be. Width measures are made orthogonal to the length axes, again between the furthest points apart of browsed form or new growth form. This procedure is identical to the Crown-Diameter method of plant cover estimation, as described by Mueller-Dombois and Ellenberg (1974).

## Other Measures

While impact may be simply evaluated through comparison of dimensions of browsed and new growth forms, knowledge of response of indicator plant species to constant and prolonged browse may be useful in further evaluating their use as indicators. For this reason, additional measures were attempted and appraised including:

Basal stem circumference: aiming to establish age classes of regeneration cohorts of tall shrub and tree species. This immediately proved impractical to measure, particularly where multiple stems (up to 15 or 16) tightly grew in confined spaces; it was never measured.

Browse form architecture: aiming at establishing the history of browse impact on individual plants. Achieved through estimating minimum and maximum length of classes of branch and stem diameter. Strongly indicative of browse history and also of age class, but measures were time-consuming and collected only on Pitcairn Station.

New growth browse: intensity of browse on the new growth as measured by the twig or branch diameter class to which the new growth had been browsed back. Readily evaluated and recorded throughout.

New growth shoot length: size of new shoots as measure of response appropriate to amount of rain fallen, time passed since controls were implemented and also vigour/health of individual plant. Readily measures and recorded throughout.

Shoot emergence: location on the plant, in reference to quarter heights, of the emergence of new shoots. Readily observed and recorded throughout. It somewhat corresponds to Keigley's browse architecture.

## Plant Species Indicators

Feral goats are generalist herbivores as shown in Table 2, which lists browsed shrub and tree species measured at survey sites on each property. Additional species were identified on the reconnaissance traverses and expanded lists will be provided in the Final Report.

Pitcairn	Yadlamalka	Yardea
<i>Eremophila alternifolia</i>	<i>Eremophila alternifolia</i>	<i>Eremophila alternifolia</i>
<i>Pimelea microcephala</i>	<i>Pimelea microcephala</i>	<i>Pimelea microcephala</i>
<i>Acacia continua</i>	<i>Acacia continua</i>	<i>Acacia continua</i>
<i>Bursaria spinosa</i>	<i>Bursaria spinosa</i>	<i>Bursaria spinosa</i>
<i>Prostanthera striatiflora</i>	<i>Prostanthera striatiflora</i>	<i>Prostanthera striatiflora</i>
<i>Acacia pravifolia</i>	<i>Spyridium phlebophyllum</i>	<i>Acacia iteaphylla</i>
	<i>Exocarpus aphylla</i>	<i>Acacia tarculensis</i>
	<i>Dodonaea viscosa ssp. angustissima</i>	<i>Acacia beckleri</i>
		<i>Babingtonia behrii</i>
		<i>Senna artemisioides ssp artemisioides</i>
		<i>Eutaxia microphylla ssp.</i>
		<i>Dodonaea viscosa var. angustissima</i>

Table 2: Plant indicator species with attributes measured at sites on the three properties included in the survey

### Response of *Eremophila alternifolia*

*Eremophila alternifolia* is common to all three stations of the semi-arid ranges. It is also prominent in more arid ranges, being a principal species of interest in monitoring at Bimbowrie.

The following data analysis is from 4 sites at Pitcairn Station. This station had received less rainfall in the six months preceding the survey, though sufficient had fallen to initiate new growth. Table 3 indicates distributions of regrowth through various ratio ranges for the height, length and width of *Eremophila alternifolia*. With ratios defined by New Growth/Browse Form dimensions, then those exceeding 1 (or 100%) indicate where New Growth dimensions exceeds those of the Browse Form. Individual dimensions are displayed in Figures 8, 9 and 10. Monitoring to demonstrate successful, ongoing feral goat control, would involve a succession of visits taking measures, which when analysed, show increasing numbers of individual plants plotting above a ratio of 1 (or 100%).

Thirty *Eremophila alternifolia* plants were measured at the 4 sites on Pitcairn Station. In the 74 days between control treatment and survey, nearly one third (9) exceed height and length dimension of the browse form. More than a third match or exceeding browse form height and length. Nearly half (14 and 13 respectively) had grown to within 80% – 100% of the browse form base dimensions of height and length. Sustained growth in the absence of goats or greatly reduced feral goat density, could quickly result in 23 of the 30 surpassing the browse form height (and 22 of 30 surpassing the browse form length). See figure 11. From the new shoot length measures, estimates of the time taken to do so could be made. Again, these results should not be considered as representative of Pitcairn, but more characteristic data can be presented similarly.

Ratio Range (%)	Height Dimension	Length Dimension	Width Dimension
0 – 40	2	2	2
[40] – 60	2	2	3
[60] - 80	3	4	7
[80] - 100	14 (3)	13 (6)	12 (4)
>100	9	9	6
<u>Total</u>	30	30	30

Table 3 Frequency of individual *Eremophila alternifolia* in ratio ranges for three dimensions on Pitcairn Station. Numbers in round brackets indicate where measures of old browse and new growth are equal. Numbers in square brackets indicate greater than, but not equal to.

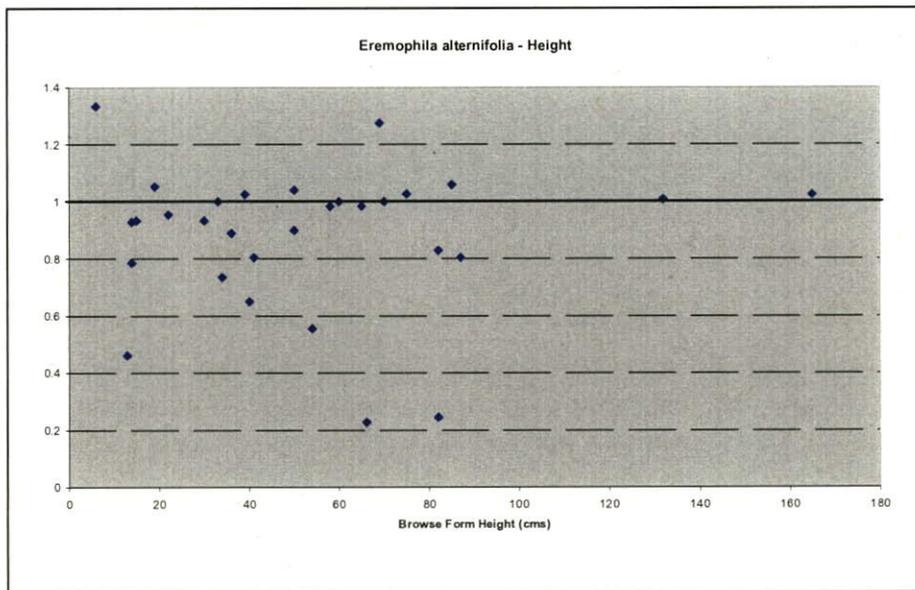


Figure 8: Plant height ratios of browsed and new growth plant forms for *Eremophila alternifolia*

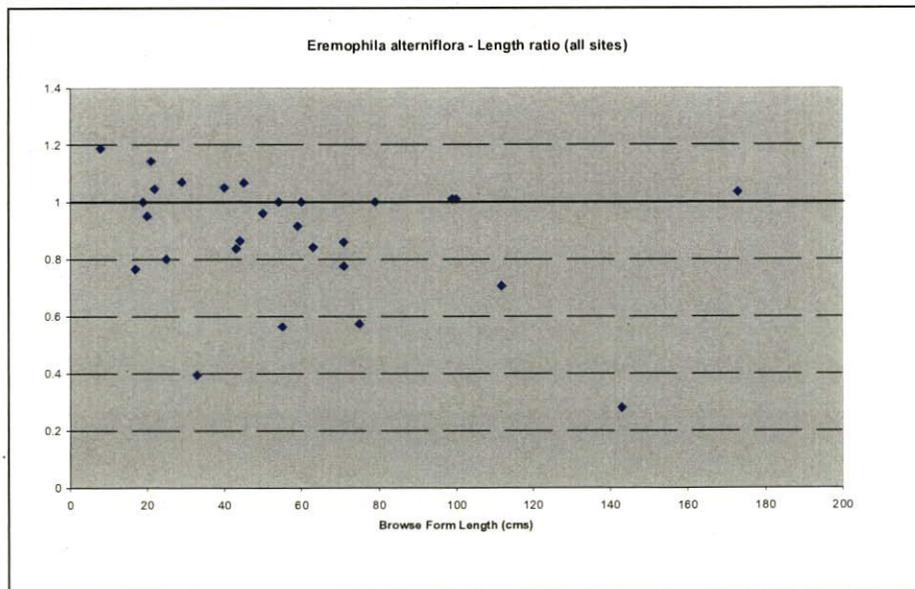


Figure 9: Plant length ratios of browsed and new growth plant forms for *Eremophila alternifolia*

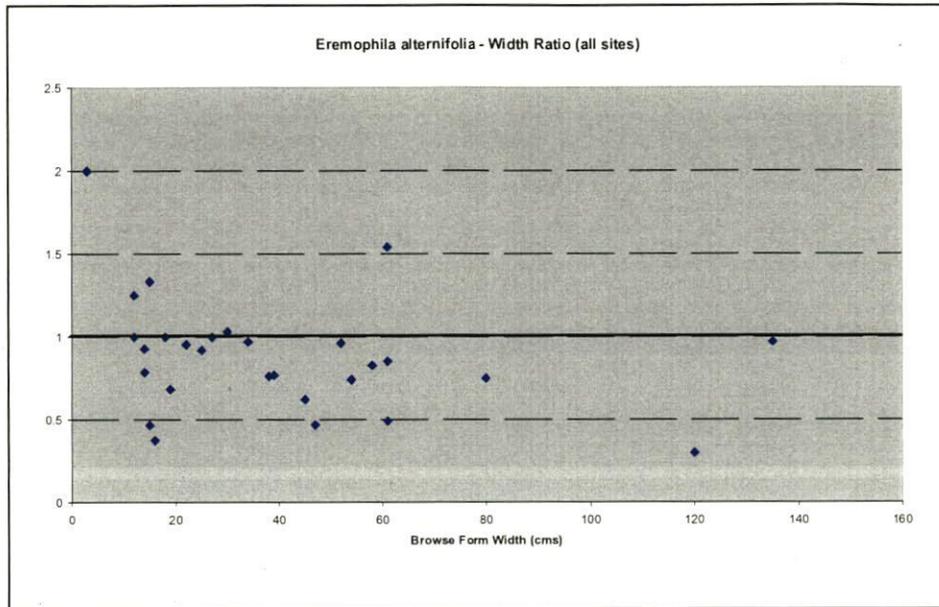


Figure 10: Plant width ratios of browsed and new growth plant forms for *Eremophila alternifolia*

In terms of Keigley's form stages, those in classes below 80%, would correspond to various degrees of *Retrogressed* form. Those in 80%-100% class would closely correlate with *Arrested* form if exhibiting current browse or possibly mark the onset of *Released* form if not browsed. Those in class above 100% correlate with *Released* form, which with additional growth become *Uninterrupted* form.



Figure 11: Illustrating that many of the measured *Eremophila alternifolia* had New Growth dimensions comparable to those of the Browsed form. Note the thickness of stems which define the browsed form.

## Discussion

Measures of plant species individuals can be easily made which readily illustrate and quantify growth, corresponding to differences in feral goat browse intensity and likely corresponding to reduction of feral goat populations. However it remains too early to evaluate control treatments as successful. Some browse pressure is noted on individual plants, but significant portions of the plants remain intact, suggesting browse is at very light levels. This may be due to shift in diet, rather than reduced goat density, as seasonal conditions are generating an abundance of forb species, which goats seem to prefer to shrub species. However, measures taken toward the end of the coming summer and showing similar results, in the absence of further rain and the desiccation of forbs, could only be taken as indicative of successful feral goat control.

Another factor precluding establishing effectiveness of control treatments, is turnaround time for feral goats to browse at the same patch. How often do they return to the same patches to browse? If this, on average is longer than the period between controls and survey, then measures have been made too soon. Again, later measures eliminate this factor in gauging success of the control program. At sites on other properties, much of the new growth was lightly browsed, but this simply stimulated growth of axillary shoots, which in turn had not been browsed, but had grown to significant lengths. The bushes were continuing to increase size despite being browsed. Also, those bushes which had been browsed, were rarely browsed uniformly, but had some shoots browsed and some intact.

A substantial growth in size of significant number of plant individuals has been easily measured and detected. Such result is consistent with successful control program.

As discussed earlier, objectives and targets for monitoring are easily adopted for these circumstances, and they relate to three separate criteria. The first is simply growth that exceeds the dimensions of browse forms as measured in a baseline year, and corresponding to increasingly surpassing an arbitrary standard. The second is growth to size at plant maturity. Shrub or tree size approaches natural limits for the species as set by its genetics and environmental situation, which is an objective standard and can be locally measured on surviving mature tall shrubs and trees. The third, applies only to tall shrubs and trees, and relates to attaining heights above 2 m, the general upper limit to goat browse.

For monitoring under sustained feral goat controls, short to medium term targets and objectives may be based on the percentages of individuals that exceed their old browse dimensions, with the initial milestone being all measured individuals at sites exceeding the older browse dimensions. Medium-term targets would be based on formerly tall shrub and tree species exceeding heights of 2 m the general upper limit of feral goat browse. Long-term targets and ultimate objectives are that these formerly browsed individuals attain the height, length and width, characteristic of mature, unbrowsed specimens. Low shrubs function as a browse intensity gauge, with degree of browse measured in any year reflecting abundance of feral goat populations.

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