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The eradication of fallow deer (*Dama dama*) and feral goats (*Capra hircus*) from Kangaroo Island, South Australia

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ABSTRACT

An eradication program for fallow deer (*Dama dama*) and feral goats (*Capra hircus*) was initiated on Kangaroo Island in 2005 and is now close to completion. The program followed established principles for successful eradication which included effective planning, gaining support from stakeholders, developing and implementing effective control and monitoring, and minimising reinfestation risks. Support for the eradication program was high based on results from community surveys and public meetings. The distribution of feral goats and fallow deer was identified initially using community observations. The area occupied by goats was divided into seven management units which were targeted sequentially, but the deer population was small and could be targeted effectively across the entire distribution. Judas goats were an essential part of the program and assisted in the location and destruction of over 1200 feral goats. Since the program began, restrictions for keeping domestic goats and deer have been tightened with the implementation of a permit system. There are no known feral goats surviving. No juvenile deer have been detected for four years and only two female deer. Monitoring continues to determine if other breeding individuals remain.

KEYWORDS

Deer; goats; island eradications; population monitoring

Introduction

In Australia since European settlement, 29 of the 315 endemic land mammals have become extinct and a further 56 species are listed as threatened with extinction (Woinarski et al. 2014). Invasive species have been identified as a main driver but because of the difficulty of controlling and eradicating these species across large areas of the mainland, conservation agencies are starting to focus management on islands where eradication of introduced species is achievable. Australia has over 8200 islands (Geoscience Australia 2017), many of which are important for conservation because they support species that are only found on islands, or they act as refugia for the last remaining translocated individuals.

A review of successful eradications has shown that large, inhabited, topographically diverse islands provide the greatest complexity for eradication success (Gregory et al.

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2014) and will only be successful with strong community support, effective control options and effective planning, monitoring and evaluation. This article summarises the steps taken to successfully eradicate feral goat (*Capra hircus*) and fallow deer (*Dama dama*) from Kangaroo Island, Australia's third-largest island (4400 km^2). The island is situated 14 km off the coast of South Australia and is nationally important for biodiversity conservation, primary production and tourism. It has a resident population of around 4500 people.

Goats were brought to Kangaroo Island nearly 200 years ago by early settlers (Nunn 1989; Taylor 2002), and feral populations became established around the west coast of the island. This has resulted in overgrazing of native vegetation and land erosion, particularly on sand dunes and around high impact areas such as caves and watering points. Feral goats are a common pest in island ecosystems, causing habitat destruction through overbrowsing, weed dispersal and soil erosion (Coblentz 1978; Parkes 1990; Biodiversity Group 1999). The removal of feral goats can have great benefits for ecosystem integrity, resulting in the recovery of vegetation, even when feral goats have impacted the area for many years (Hamann 1979, 1993; Parkes et al. 2002; Campbell & Donlan 2005). Fallow deer became feral on Kangaroo Island in the 1990s when fencing around a deer farm deteriorated and the deer escaped. A community control program was implemented but with inadequate financial and professional backing, the program failed.

In 2005, with the call for demonstration sites by the Invasive Animal Cooperative Research Centre, funding was committed to develop a program for the eradication of goats and deer over a six-year period and commitment for additional ongoing funding was sourced from other government agencies. An eradication program for feral goats and deer was implemented and is now in the final monitoring stage. This article outlines the crucial components of the program that were necessary to achieve successful eradication of these species on a relatively large and inhabited island. The program incorporated the principles for successful eradication outlined by Parkes (1993) and Bomford and O'Brien (1995). The major components addressed during this program were:

(1) assess, gain and maintain public and government support for the program;
(2) plan for cost-effective eradication and implement the program using skilled and dedicated staff;
(3) develop and implement control options that can reduce the population faster than the reproduction rate, and ensure every individual is at risk of destruction;
(4) detect individuals at low densities, and continue to monitor areas to ensure no undetected populations remain;
(5) measure and describe the impacts of the pest species so the community can understand the importance of the program; and
(6) minimise reinfestation risks by developing effective management and permit requirements for domestic populations.

Assess, gain and maintain public and government support for the program

Public opposition is the most common obstacle to the implementation of an eradication program, so it is important to gauge public opinion prior to initiation (Genovesi 2007; Oppel et al. 2011). On Kangaroo Island, public support was gauged through public

meetings, scoping meetings targeting sectors of the community, and through conversations at local shows and field days. Issues addressed included perceptions of feral goat and deer impacts and benefits, requirements for managing domestic goats and deer, and the level of resident support for an eradication program. The community also helped to clarify the distribution of feral goats on the island by identifying locations of sightings. Articles about the feral eradication program were placed in the local newspaper and newsletters, and information was provided at public events and through displays in public places, such as the airport and library window.

A survey, designed to determine the support for feral and domestic goat control, was distributed to all households. This resulted in an 8 per cent return rate (126 respondents). Overall 94 per cent of the local community strongly supported eradication. Additional questions relating to management of domestic goats found that they were kept for meat, milk and pets. Half of the community (52 per cent) supported the exclusion of domestic goats from the island, and 65 per cent believed that domestic goat management should be improved through goat registration and more stringent fencing requirements.

Deer on the other hand were regarded as a threat to the stud cattle industry, because of the potential for deer to carry Johne's disease, and they were becoming a road hazard as the population increased in abundance. At the beginning of the program, there were only five landholders who owned deer, of whom only three had more than two individuals.

One of the greatest challenges for the program was gaining access to all private properties that were occupied by feral goats and deer. Most landholders were supportive and accommodating but others used the animals as a hunting resource and did not want to see them removed.

It was important throughout the program for control officers to maintain one-on-one contact with all relevant landholders. Officers ensured that they followed all procedures required by the landholder when on their property. Public lands (conservation reserves) were selected first for goat eradication. This was done to demonstrate to the community that the program could achieve success and to reduce the likelihood of community criticism that private land was being targeted while goats were uncontrolled on government lands. It was also logistically easier to start eradication in an area with one tenure, and on the edge of the distribution so immigration was minimised.

Planning and implementing a cost-effective eradication program

Prior to 2005, goat management on Kangaroo Island involved recreational hunting on the north coast and intermittent shooting by National Parks staff and Sporting Shooters in conservation areas on the west coast. Few records were kept on the intensity and extent or success of control operations, and little was known about the impact, distribution or abundance of the feral goat population. Management did not have the resources needed to maintain an ongoing program. Similarly, deer control was reliant on landholders and recreational shooters targeting animals opportunistically. Additionally, there was conflicting information regarding the number of deer that had escaped and the number destroyed by landholders.

As a first step, information about goat and deer distribution was gathered from community sightings and potential impact of both species was assessed from information collected by local naturalists and Parks staff and through a literature review. Management strategies were developed for each species which encompassed timeframes, roles and

responsibilities of partner organisations. Long-term funding to allow the program to run for several years was essential to support a team with professional hunting skills and data collection and monitoring expertise. The involvement of control staff with a good standing in the rural community and a good knowledge of local conditions was critical, to maximise trust and minimise the time needed to get the program underway.

Developing and implementing control options to reduce the population faster than replacement and ensuring every individual is at risk of destruction

Deer and goats have very different ecological characteristics and require very different control strategies. Goats produce up to three young, 1.5 times a year and can double their population every 1.6 years (Parkes et al. 1996). They prefer browse species over grasses and find a wide range of Australian native species palatable (Dawson & Ellis 1996; Parkes et al. 1996). They are gregarious and an ideal species for the use of Judas animals, radio-collared goats which find feral groups or individuals which can then be destroyed, leaving the collared goat to find another mob (Campbell & Donlan 2005; Henzell 2008).

Deer, on the other hand, are slow breeders producing only one young per year (Mulley 2008). They occupy a wide range of habitats including improved pasture, pine forests, native forest and scrubland (Nugent & Asher 2005). They have a varied diet, generally preferring to graze but will eat browse when grasses are scarce (Nugent & Asher 2005). The species is gregarious but, when densities are low, they tend to be solitary or move in small groups. Their timid, nervous nature and habit of hiding in thickets of vegetation makes them difficult to detect (Nugent & Asher 2005). On Kangaroo Island, deer remained close to the release sight residing in eucalypt and pine plantations, and grazing areas surrounded by mallee woodland.

Goat control

The area occupied by goats was too large to address comprehensively; therefore, it was divided into seven management units (MUs) based on land area, natural barriers for containment and road lines for access (Figure 1). The creation of MUs was designed to deliver systematic eradication of goats sequentially over a set of discrete and achievable geographic areas, each with limited potential for reinvasion.

Judas goats were selected as the major tool to assist control. Initially, a trial was undertaken in one MU to assess methods, costs and the feasibility of complete eradication. The MU selected for the trial (MU1) had a small isolated goat population located on one of the major rivers. The land uses included conservation, sheep grazing and forestry. The eradication trial was completed in 12 months with the removal of 45 goats, and eradication of feral goats from Kangaroo Island was deemed to be achievable.

Deploying Judas goats

The use of Judas goats followed the standard operating procedures developed by the Department of Primary Industries, NSW (Sharp & Saunders 2004). Most Judas goats used on Kangaroo Island were obtained from feral mainland populations. All the goats were in good condition, between 6-36 months of age, calm in nature (not highly alert

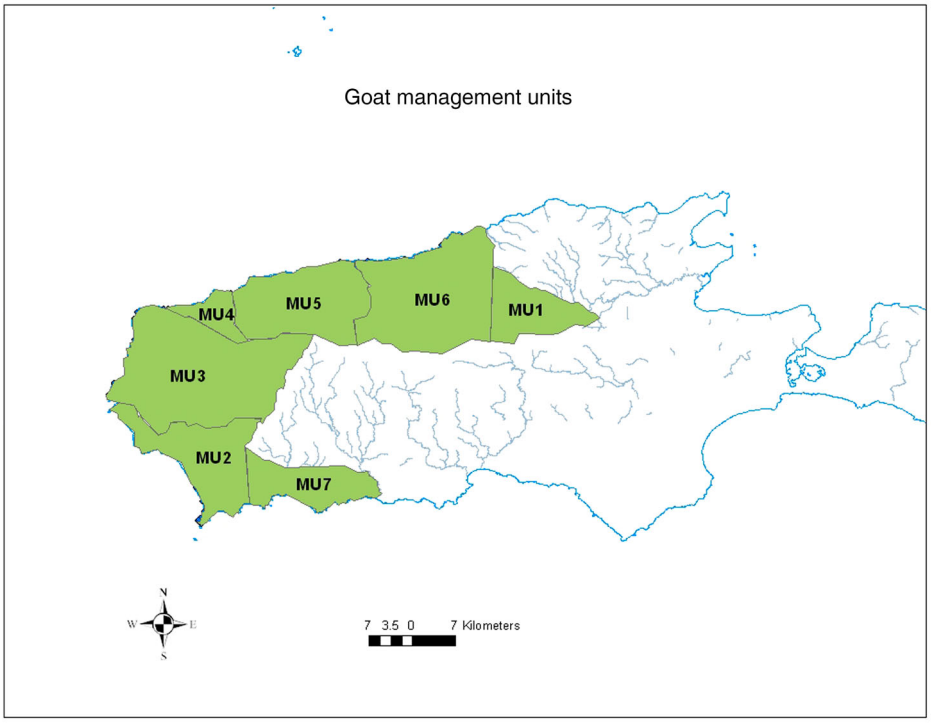

Figure 1. Kangaroo Island area of goat distribution divided up into seven MUs.

or dominant) and white in colour. White Judas goats were easier to spot at a distance or in thick vegetation and contrasted with the local coloured goats. This helped with identification and reduced the chances of accidental shooting. Over 90 Judas goats were used during the program.

To prevent breeding, all Judas goats were sterilised at a local veterinary clinic either by vasectomy (males) or transection of the fallopian tubes (females) so that sexual motivation was maintained. This type of sterilisation allows females to continue to cycle into oestrus every 21 days during the breeding season and retain the need to socialise. In contrast, breeding female goats with accompanying young are less sociable for one month to a year after giving birth. A vasectomy has no negative effects on the social and sexual behaviour of male goats (Campbell et al. 2005).

Judas goats were kept in a pen for a week to allow all weed seeds to pass through their gut and thereby reduce the chance of introducing new weeds to the release site. Each goat was photographed, measured, weighed, ear tagged, fitted with a radio-collar and then released in an area of the MU known to have goat sign. Most of the released goats soon located the other feral goats in the area. Information on movements, habitat use and social behaviour was collected to improve understanding of goat ecology on Kangaroo Island, and to improve hunting and shooting operations (see Rainbolt & Coblentz 1999). Judas goat movements were monitored intensively in MUs 1, 2, 3 and 7 in the first two years. MU7 had historical reports of feral goats but the released Judas individuals failed to locate any feral goats and no further sightings have occurred. The feral goats occupying the coastline generally moved along a 9 km stretch of coast with some groups

moving inland along creek lines for a similar distance. Individual Judas goats were released 2–5 km apart to reduce the chances of them forming their own group.

VHF collars were used predominantly because they were cheaper and had a longer battery life than satellite collars. They were more suitable for use in easily accessible terrain traversed on foot or by vehicle. In remote and inaccessible locations, satellite/VHF collars were found to be more suitable because they enabled the goats to be located remotely prior to tracking.

Control operations

Following the feasibility trial and establishment of population monitoring in MU1 (Parndana), the focus moved to MU2 and MU3 along the west coast of Kangaroo Island in Flinders Chase National Park (Figure 1). This subpopulation occupied a narrow strip of coastal vegetation dominated mostly by heathland and often only accessible on foot or by air. Park closures were required for control operations and were put in place every three months, avoiding the holiday periods.

Initially feral goats were targeted by walking the length of this part of the coastline. As the numbers of feral goats declined, control activities focused around the Judas goats. The west coast (MU2 and MU3) was completed by 2009 with the removal of 257 goats and the program moved to the north coast where the terrain was steeper, the vegetation thicker and property ownership more diverse. By 2012, MU4 (Cape Torrens) and MU6 (Middle River) were also completed with the removal of 462 goats leaving one MU, Western River MU5. This area was particularly challenging due to thick vegetation and steep topography making access difficult. Most goats were destroyed by 2013 but the last few were difficult and required extra detection methods including camera traps and helicopter surveys. The last three goats were shot in February 2016 (Figure 2). Monitoring using Judas goats and cameras was still underway at the time of writing to ensure no goats remained.

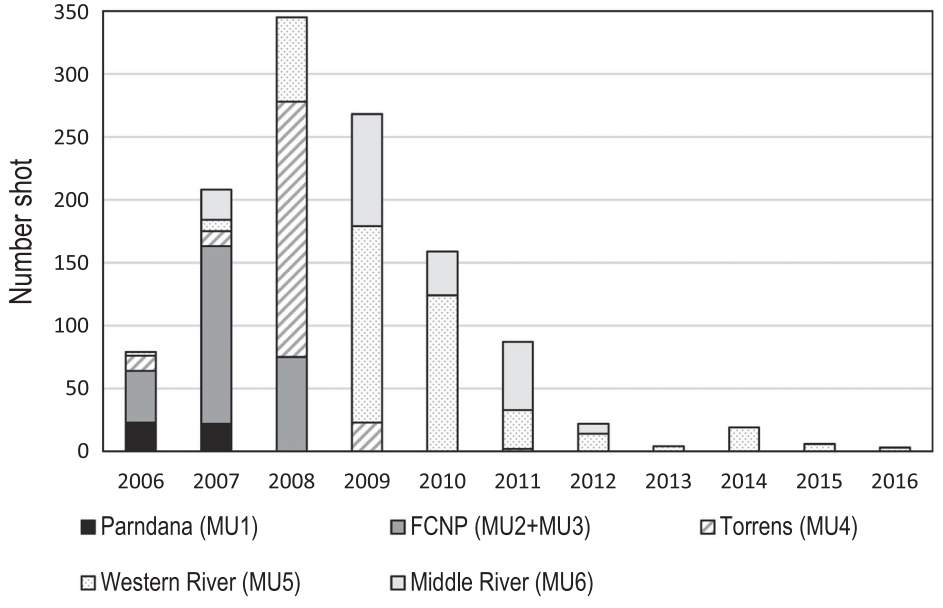

Figure 2. The number of goats shot in each MU by year (FCNP included MU2 and MU3).

On four occasions, aerial control was conducted with a helicopter and qualified shooters. The first aerial shoot was undertaken in early 2008 following a large bush fire, and 111 goats were destroyed in two days but a sizeable proportion of goats were undetected by helicopter spotters because they sheltered in thick vegetation or in caves. The aim of the second aerial shoot in 2012 was to target the few remaining goats and search areas for undetected feral goats. Five goats were destroyed during one day of control, which was most of the remaining goats in MU6. Two more surveys were undertaken to search for remaining goats but no goats were detected.

Deer control

Most of the deer population was found to be within a 15 km radius of the release site and genetic analysis indicated that individuals were traversing the whole area so control was not divided into smaller units (Sarre et al. 2008). In addition, the deer were rarely seen in a group of more than three, so Judas animals were not likely to assist control operations. Our ability to destroy the population faster than the reproductive rate was reliant on applying sufficient hunting effort. Hunting success was improved by learning about seasonal movements and habitat use, and by acting on community sightings through a 'dob in a deer' program. Camera traps were used in the later stages of the program to identify the number of remaining individuals.

Detecting animals at low densities and monitoring areas post eradication

An eradication program is only complete once the breeding population has been destroyed. However, identifying when the program has reached this point is difficult. If eradication is called too early, the program will fail; if control continues beyond the point of eradication, resources maybe wasted by carrying out control operations when no animals remain. We used very different methods for the two species to estimate the rate of population decline and finally to monitor post eradication.

Goats

After the last known feral goat was destroyed in a MU, Judas goats were monitored for a further 12–24 months. If no feral goats were found, Judas goats were removed and the area was checked for goat scats and tracks annually by walking the length of the MU and focusing on previously favoured areas such as water holes and river outlets. A media program 'bleat on a goat' promoted the need for community members to report sightings and rangers, fishermen, landholders and tour operators were regularly asked if they had seen any goats. In the last MU, goat detection was more difficult due to the steep terrain and thick vegetation so camera traps were used more intensively to quantify the number of feral goats remaining based on unique identification of individuals. All known individuals have now been destroyed.

Deer

We used a range of methods to detect and monitor trends in the population reduction of deer. These included monitoring changes in age structure based on tooth eruption and

wear patterns, monitoring the time taken to destroy individuals, and estimating the probability of occupancy using tracks detected at dams. Towards the end of the program, remote cameras were found to be more effective to detect deer and photographs could be used to identify individuals based on coat pattern.

Changes in age structure of destroyed deer

Changes in age structure of a hunted population can be used to infer whether a population is increasing or declining (Caughley 1977). Tooth eruption and wear patterns were used for aging the deer in one-year intervals up to the age of 6.5 years (as developed by the Game Management Services Unit, Tasmanian Department of Primary Industries, Water and Environment). This allowed for the age structure of the deer population to be compared among years.

In the period January 2006 to June 2015, 231 deer were shot on Kangaroo Island. One hundred and eighty-two were aged according to tooth eruption and wear and divided into five age classes (Figure 3). Fawns (<12 months) accounted for a high proportion of shot animals (0.72) when culling started in 2006 but dropped to zero by 2012/2013.

Catch effort

Catch effort was calculated as the average number of hours required to destroy a deer. This was determined by recording the number of person hours spent searching and shooting deer each night and the number of deer destroyed. Two people were generally involved in culling operations. Catch effort was compared with previous years to identify annual trends.

Catch effort on Kangaroo Island increased considerably from 18 hours per deer in 2006/2007 to 173 hours per deer in 2012/2013, despite the control officers improving their knowledge and skills, and changing their hunting strategies accordingly (Figure 4). In 2013/2014, remote cameras were used to detect the presence of deer, which reduced

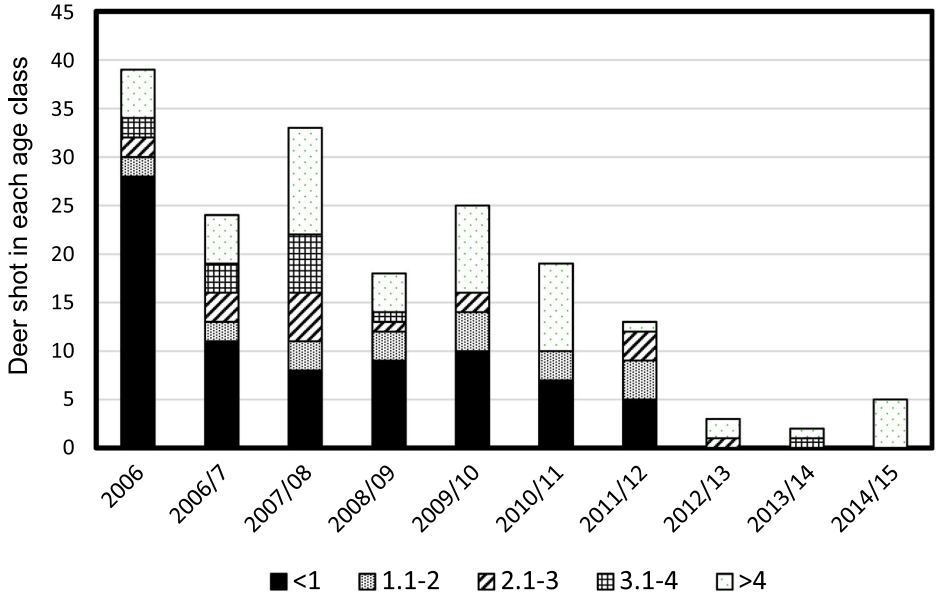

Figure 3. Age structure of shot deer from 2006 to 2015.

the time taken to find and destroy deer. Only two females are now known to remain and less effort is going into active searching for those deer, with a greater reliance on camera trapping across the previous range.

Deer occupancy and detection

A track-based monitoring program focusing on watering points was implemented to identify deer distribution and probability of occupancy. Monitoring of deer tracks at dams was used to detect deer following a trial, which showed that searching for tracks at dams was more effective than track plots or spotlighting along access roads. Properties were selected for monitoring within the suspected deer distribution if sheep were thought to be absent. Sheep were absent from most of the forestry plantations in the study area. The absence of sheep on study sites was important because sheep tracks are similar in size and shape to those of deer (Moseby et al. 2009). Flocks of sheep coming to drink at a dam also tended to obliterate tracks of other species.

The dams were checked in late summer when free-standing water was restricted to dams and the larger waterholes along creek lines. Dams were sampled up to three times with at least a five-day interval between samples. Track size could be used to identify the presence of large, medium and small individuals. Occupancy estimation and modelling were conducted using PRESENCE and in accordance with techniques developed by MacKenzie et al. (2006). Between 170 and 242 dams were sampled, up to 40 km from the release site, each year.

Deer tracks were detected at 63 of the 170 dams sampled in 2009, providing a naive occurrence of 0.37. By 2013, deer sign was detected at only four of the 242 dams sampled (naive occurrence 0.016) (Table 1). The probability of occupancy in the first year (2009) was 0.41 ± 0.08, which declined to 0.06 ± 0.01 (2013), giving an annual rate of decline in occupancy of between 23 per cent and 62 per cent per annum (Southgate et al. 2013).

The dam monitoring provided an effective method to cover the potential deer distribution within a 2–3 months period while deer were reasonably abundant and widespread. Remote camera traps were trialed in 2013 and found to be more effective than dam

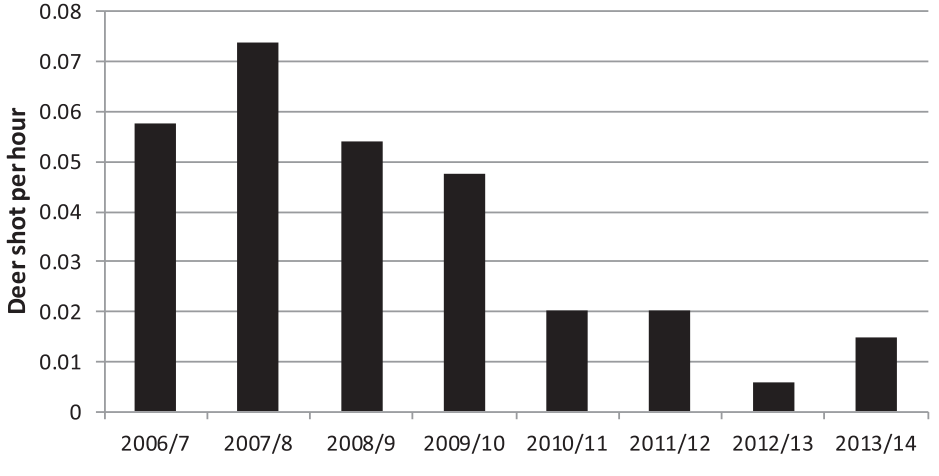

Figure 4. Catch effort (hours of hunting per deer) for deer shot between September 2006 and June 2014.

Table 1. Probability of occupancy calculated from detection of tracks at dams.

Year	Probability of occupancy
2009	0.41 ± 0.08
2010	0.26 ± 0.05
2011	0.16 ± 0.03
2012	0.10 ± 0.02
2013	0.06 ± 0.15

monitoring at detecting deer at very low densities. The cameras were deployed 500 m apart on each property and left for 14 days. The limited number of cameras available reduced the number of properties that could be sampled simultaneously but the images of deer captured provided valuable information on the sex, size, identity (based on coat pattern) and behaviour of the remnant individuals. Both the camera traps and the track plots support the view that recruitment stopped in 2012 and the eradication is effectively complete.

Developing an understanding of the impacts of goats on Kangaroo Island

Potential impacts of deer were not monitored because of their recent introduction and relatively small population, but a vegetation monitoring program was established to determine plant community responses to a goat free environment.

When the eradication program began, knowledge of the impact of feral goats on Kangaroo Island native plant species was limited to anecdotal information from community members and local naturalists, so rumen samples were collected and analysed from 62 destroyed goats to identify what plants they were consuming. A total of 75 plant species were identified in the samples. The majority were native species, but weeds were also present, including cape weed (*Arctotheca calendula*), phalaris (*Phalaris aquatic*) and barley grass (*Hordeum* spp.). The plant consumed most frequently (45 per cent of gut samples) was drooping she-oak (*Allocasuarina verticillata*), which is an important food source for the endangered glossy black-cockatoo (*Calyptorhynchus lathami halmaturinus*).

The growth of *Allocasuarina verticillata* and other plant species was monitored annually from 2008 at 11 sites, distributed across the four MUs on the north coast. Twenty-five-metre transects were established and individual plants were mapped and their growth monitored. Preliminary results suggest that the removal of feral goats has resulted in higher recruitment and survival rates of *A. verticillata* and an increase in species diversity. On some sites, there has been an increase in the cover of succulent species such as *Tetragonia implexicoma*, *Disphyma crassifolium*, *Rhagodia candeolleana*, *Carpobrotus rossii*, *Zygophyllum billardierei* and *Enchylaena tomentosa*, but the monitoring needs to continue to allow time for the plants to respond fully. Photopoints have shown a dramatic change in vegetation cover over time. Areas of high feral goat use, such as caves, were devoid of vegetation before control activities began in 2005, but now support a thick ground cover (Figure 5).

Minimising reinfestation risks by developing effective management of domestic populations

While domestic goats and deer reside on Kangaroo Island, there will always be a risk of a feral population re-establishing in the wild. To counter this possibility, the state government

Figure 5. Difference in vegetation cover at a cave in MU2 in (a) 2005, left, and (b) 2012, right.

has revised the legislation so that the keeping of domestic goats and deer requires a permit from the Kangaroo Island Natural Resources Management Board. A permit to keep deer could be justified if there was great benefit to the community, but mandatory conditions including double fencing, the keeping of log books to identify the fate of individuals, tagging of individuals, and the requirement for handling facilities would be imposed. Domestic goats can be kept if there is low risk of a feral population establishing.

The risk assessment criteria include the history of escapes, nature of the enterprise (pet, milk, meat), location in relation to terrain, vegetation, proximity to human habitation, ability to detect an escape based on vegetation cover, fencing standards, and stock monitoring, and consequence of escape and the chance escapees will enter suitable habitat.

Conclusion

Successful eradication of goats and deer from Kangaroo Island is close to completion with only two female deer known to be alive, and no known goats, although monitoring is still underway to ensure complete removal of breeding individuals. In addition, the management of domestic animals also needs to be continued.

The program has demonstrated that a well thought out strategic approach can work on a large occupied island when the community is supportive and the resources and skills for control and monitoring are available. Long-term funding and departmental support, staff covering a diversity of skills, and a network of professional people for advice, have been important ingredients.

Monitoring suggests that species diversity, *Allocasuarina* and succulent plants are recolonising now the feral goats have been removed. These results are consistent with those from other islands where feral goats have also been removed and the vegetation has responded rapidly (Campbell & Donlan 2005). This eradication program will benefit other species, such as glossy black-cockatoos, which are dependent on the recruitment of species impacted by feral goats.

Goat eradication has taken longer than initially anticipated (six years) due to a range of issues including thick vegetation making access for control difficult, some Judas goats not performing and remaining solitary, political and policy change due to organisation amalgamation, the need to re-negotiate access to properties when they changed ownership, and the difficulty for field staff to maintain momentum and hunting skills when there were few

individuals left. The deer eradication on the other hand was faster than anticipated, probably because of the slow reproductive rate, high site fidelity and the inability of males to mate with sparsely distributed females. The dry summer conditions may also have affected population growth rates.

The benefits of the program are considerable, including savings to government agencies and landholders with no ongoing management, improvements in habitat quality and plant diversity, removal of competition with stock for food and water, and removal of vectors for disease and the spread of weeds.

Unsuccessful eradications are generally attributed to a lack of political and community support, inappropriate methods that cannot destroy individuals faster than they breed, lack of effort and the failure to detect the final few individuals at low densities. The Kangaroo Island program has been successful to date and now requires the confirmation that no undetected populations remain on the island. While domestic herds of deer and goats are permissible, resources will be needed to assess the risk of escape, to monitor domestic stock, and to ensure no more populations become established.

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Disclosure statement

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