BACKGROUND DOCUMENT

for the

THREAT ABATEMENT PLAN

for competition and land degradation by unmanaged goats

2008

Department of the Environment, Water, Heritage
and the Arts

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Front cover photo: Unmanaged goats on northern Kangaroo Island, March 2008, by Michael Cresshill

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Contents

1. Introduction

This is the background document to the *Threat abatement plan for competition and land degradation by unmanaged goats* (DEWHA 2008). It provides information on goat characteristics, biology and distribution; impacts on environmental, economic, social and cultural values; and current management practices and measures.

The threat abatement plan (TAP) establishes a national framework to guide and coordinate Australia's response to competition and land degradation by unmanaged goats. It identifies the research, management and other actions needed to ensure the long-term survival of native species and ecological communities affected by unmanaged goats. It replaces the *Threat abatement plan for competition and land degradation by feral goats* published in 1999 (EA 1999).

1.1 Goat distribution and abundance

Rangeland goats (*Capra hircus*), both managed and unmanaged, are found across approximately 2 million square kilometres of Australia; in all states, the Australian Capital Territory and some offshore islands, including a few islands of the Northern Territory (see Figure 1.1).

The greatest numbers of rangeland goats are found in the arid and semiarid pastoral regions of Queensland, New South Wales, South Australia and Western Australia (Parkes et al. 1996), but the greatest densities occur in areas of higher rainfall (Fleming 2004). Goat numbers appear to be stable in the semiarid rangelands, although they may be increasing on the western slopes of the Great Dividing Range (Forsyth and Parkes 2004).

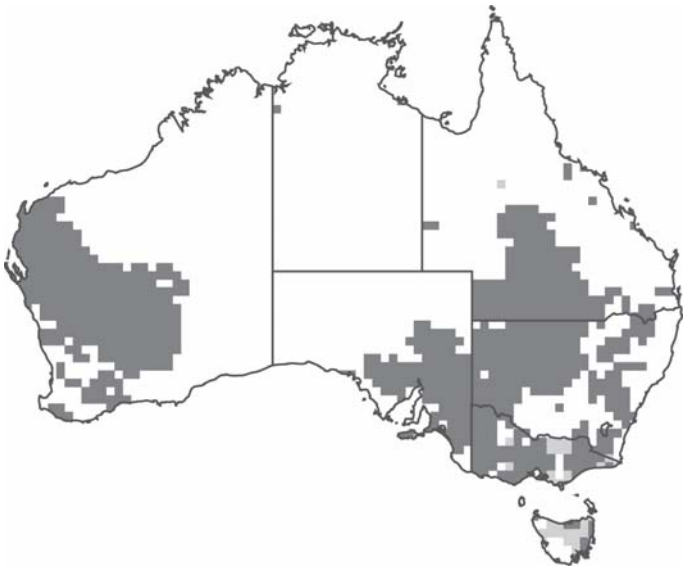
Southwell et al. (1993) estimated that eastern Australia has nearly one million 'feral' goats. A few years later, Parkes et al. (1996) estimated that Australia had about 2.6 million 'feral' goats. However, the authors considered this a conservative figure in view of the number of animals harvested — about one million per year from 2001 to 2003 (Forsyth and Parkes 2004).

Rangeland goats are absent from the mainland of the Northern Territory, but they are found on a few offshore islands. In the late 1980s and early 1990s, several pockets of unmanaged goats north and northeast of Alice Springs were eradicated. No known populations currently occur in the southern region of the territory.

The distribution of unmanaged goats is limited by several factors, including:

- type and nutritional quality of vegetation
- availability of shelter
- availability of water during dry times
- occurrence of parasites and diseases, and
- predation from dingoes and wild dogs in areas where these predators occur.

Figure 1.1 Occurrence of goats, *Capra hircus*



Source: IA CRC and NLWRA (2007)

1.2 Impact of goats

Despite observations that unmanaged goats may contribute substantially to the total grazing pressure in rangelands, only a small number of studies have specifically examined the impacts of goats on vegetation in arid Australia. The underlying explanation for this lack of knowledge on unmanaged goat impacts is the difficulty in separating their impacts from that of similar sized herbivores, particularly sheep and kangaroos. Most evidence of unmanaged goat impacts on vegetation is anecdotal or is confounded due to the presence of other grazing animals.

Grazing by introduced herbivores, where a sustainable management regime is not in place, has had well documented effects on the vegetation of arid Australia. These effects include:

- a general reduction in vegetation cover
- an increase in the amount of bare ground, changes in the composition of perennial and annual vegetation selecting against palatable species (Landsberg et al. 1997, Ludwig et al. 1997)
- loss of soil nutrients (Sparrow et al. 2003)
- changes in the density and composition of the seed bank (Landsberg et al. 1997, Kinloch and Friedel 2005)
- decreased seed production (Letnic 2004)
- increased soil erosion (Wasson and Galloway 1986), and
- the disruption of microbiotic soil crusts that play an important role in nutrient cycling (Eldridge and Greene 1994).

In high densities, unmanaged goats present a potential threat to plant communities because of the large number of plant species that are palatable to them (Squires 1980, Henzell 1993, Parkes et al. 1996). Moreover, the ability of unmanaged goats to survive on low-nutrient fibrous vegetation (Doyle et al. 1984) enables them

to continue to feed under adverse environmental conditions, increasing the risk of overgrazing.

In a short-term study in shrublands of semiarid Queensland, Thompson et al. (1999) found that goat impacts on vegetation were difficult to detect because of the over-riding influence of varying rainfall on vegetation structure and composition. Unmanaged goats were not identified as a threat to the regeneration of plant species in chenopod shrublands in South Australia (Tiver and Andrew 1997). However, enclosure experiments have demonstrated the potential of unmanaged goats to overgraze, prevent the regeneration of plants and cause soil erosion (Harrington 1979, Harrington 1986, Greene at al.1998). Such overgrazing is likely to be both prevalent during drought and exacerbated by the impacts of other herbivores (Henzell 2000).

In a semiarid environment in South Africa, erosion and grazing by goats stocked at high densities reduced the carbon content of soil (to a depth of 10 cm) by 35 per cent and plant biomass carbon by 75 per cent (Mills et al. 2005). The carbon content of soil is associated with soil fertility and the capacity of soil to retain moisture. The results of this study highlight the impacts that overgrazing and erosion due to goats can have on soil fertility and carbon sequestration in ecosystems.

In a forested landscape in eastern Australia, grazing and trampling by goats reduced vegetation cover and increased soil erosion (Bayne et al. 2004) but did not have significant impacts on plant species diversity or the abundance of most species. Goats can also foul waterholes and introduce weeds through seeds carried in their dung.

Control of unmanaged goats should be integrated with the management of other large herbivores to ensure that the total impact of grazing is maintained within ecologically sustainable limits. At densities of five per square kilometre, unmanaged goats can contribute 10–25 per cent of the total sustainable grazing pressure (Parkes et al. 1996).

Competition and land degradation by feral goats are listed as a key threatening process under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Of the threatened species listed under the EPBC Act, unmanaged goats are considered a threat to 8 species of birds, 3 mammals, 1 insect and 44 plant species, with 2 of the plants (*Acacia unguicula* and a *Pultenaea* species) considered critically endangered (see Appendix A of the current TAP).

For each key threatening process under the EPBC Act, the Minister must decide if a TAP is to be prepared. The Act prescribes the content of a TAP and the mechanisms by which it is to be prepared, approved and published. The relevant sections of the Act are reproduced in Appendix A.

1.3 Goat biology

Under favourable environmental conditions, goat populations can increase by up to 50 per cent each year (Mahood 1985, Maas and Choquenot 1995, Parkes et al. 1996, Fleming 2004). There are two breeding seasons per year, and twins and triplets are common.

Goats tend to browse, eating shrub and tree matter (leaves, twigs, bark, flowers, fruit and roots), but they will also graze alongside sheep in pastoral areas, and will switch to grass and forbs (herbs other than grass) when these are green (Wilson et al. 1975, Harrington 1986). Their feeding habits in more temperate regions tend to be seasonal (O'Brien 1984).

As generalist herbivores, goats can occupy a variety of habitats (Coblentz 1977). They prefer woodland to grassland, and their ranges centre around water sources in arid or semiarid areas where they cannot obtain enough water from forage and dew (Fleming 2004). Goats need to drink every two to three days during summer (Dawson et al. 1975, Fleming 2004), but can otherwise extract most of their water requirements from their food.

At least 20 goat-sized herbivores per square kilometre can be supported in rangelands with annual rainfall of 240 millimetres (Bomford and Hart 2002). Estimates of actual goat densities in arid and semiarid rangelands range from 0.5 per square kilometre in central and southeastern Western Australia to 5 per square kilometre in eastern South Australia (mean annual rainfall 240 mm). In areas of higher rainfall, such as Coolah in central eastern New South Wales in the Great Dividing Range (mean annual rainfall 740 millimetres), goat densities have been estimated at between 26 and 98 per square kilometre (Fleming 2004).

Unmanaged goats live mostly in separate male and female herds, which mix during the breeding season in autumn and winter (Parkes et al. 1996). Herd ranges overlap and share common ground but male herds tend to cover larger areas. Range depends on rainfall, particularly for female herds. Herds or mobs consist of about 2–6 goats in arid and semiarid regions, but can contain 40 or more goats in areas of higher rainfall (Fleming 2004).

2. Controlling unmanaged goats

Complete removal of unmanaged goats from the Australian mainland is well beyond the capacity of available techniques and resources because the species is well established across a vast area. Eradication from offshore islands (or from mainland areas that have similarly isolated populations), is feasible and has been achieved in Queensland on Woody Island using Judas goats and on Townshend Island by dingo predation (Jago 1999). Tasmania has attempted to eradicate its unmanaged goats.

Parkes et al. (1996) reviewed current knowledge on techniques for suppressing unmanaged goat populations. The review concluded that the main deficiencies with control programs are associated with decisions on whether to attempt local eradication or strategic management. Where operations are undertaken, the frequency of control activities and the target densities required need to be decided.

A review of the 1999 goat TAP (Hart 2005) proposed that conservation and commercial use objectives be aligned. Commercial harvesting of unmanaged goats is the main form of control outside reserve areas. From a conservation perspective, the review suggested that unmanaged goats should be controlled in the context of grazing management in general.

The control of unmanaged goats will best be achieved where integrated approaches target local or regional circumstances, and use the most appropriate suite of options to reduce and control population numbers and their impacts. A very important part of the development of local approaches is working with primary producers to address their economic interests in harvesting goats.

Careful attention is needed in the selection and implementation of control techniques to minimise any non-target impacts resulting from the control activities. The techniques discussed here are mustering, trapping, fencing, shooting, use of Judas goats, fertility control, poisoning and biological control.

2.1 Mustering

Although mustering unmanaged goats for slaughter or live sale is labour-intensive and limited to relatively flat terrain (Harrington 1982), it is efficient due to the goat's large size, and their diurnal and social habit. The advantage of this technique is that the cost is partly or fully offset by the sale of the goats harvested. Two methods are used (Parkes et al. 1996):

- aerial mustering using helicopters or light aircraft to flush animals out of dense vegetation or inaccessible terrain, followed up by a ground team
- ground mustering on motor bikes or horseback, usually with the help of dogs.

Mustering is not a suitable control method in rugged, forested terrain in high rainfall areas and has been relatively unsuccessful in local eradication programs in Tasmania (Hart 2005). At low densities (less than one goat per square kilometre), mustering alone becomes uneconomical (Henzell 1984). An estimated one million goats are mustered each year in Australia (Parkes et al. 1996).

The success of mustering in reducing the population can vary greatly from a low of 26 per cent reduction (T Brill, NSW Agriculture, pers comm) to a high of 80 per cent (Henzell 1984). Effectiveness is also related to the value of a goat (Henzell 1992a), with landholders intensifying efforts when goat prices are high. Parkes et al. (1996) described a number of management strategies on pastoral land that involved mustering both alone and in combination with several other techniques. Lower goat densities can be achieved by combining mustering with more expensive techniques and technologies.

2.2 Trapping

Trapping groups of goats around watering points can be an effective and efficient control technique (Harrington 1982) that can be used year-round in arid and semiarid regions (seasonally in other regions); however, it depends on the availability of alternative water sources. Trapping involves the construction of goat-proof fences around water points, incorporating one-way entrances or jump-down ramps that allow access but prevent the goats from exiting (Parkes et al. 1996). Once captured, the goats may be sold to offset the costs of capture, or be humanely destroyed.

This technique is most effective in arid or semiarid regions where water sources are limited. In areas of higher rainfall, trapping is effective only in dry times when goats are obliged to find water and there is no access to alternative water sources. Traps must be robust enough to contain goats. A suitable period of training is required for the animals to become familiar with the trapyard (Bellchambers 2004).

Animals must be provided with adequate food, water and shelter while in the trap. Trapped wildlife should be released immediately and goats removed to temporary holding paddocks, or to abattoirs for destruction or live sale. Traps are used at water points, but if used incorrectly, there are potentially harmful impacts on non-target species and animal welfare concerns. A combination of management and engineering strategies can address this, such as the immediate removal of non-target animals and the provision of escape gates for macropods (Bellchambers 2004). Local knowledge of other species that may be at risk will assist in identifying the most suitable trap design and use.

Successful trapping of goats is possible at both high and low goat densities, and rates of capture have been estimated at more than 80 per cent (Bellchambers 2004). However, the removal of large numbers of goats is not the same as removal of a significant proportion of the local population, and care should be taken to consider the mobility of goats and their high reproductive potential.

2.3 Fencing

Fences are expensive to establish and maintain, may not permanently stop the movement of all goats and could have an impact on the movement of wildlife. Therefore, fencing should only be used as a tactical technique in a management program (Parkes 1990). Fencing can:

- create short-term manageable units during an eradication campaign (Baker and Reeser 1972, as cited in Parkes et al. 1996)
- limit recolonisation during sustained control (Parkes 1990)
- limit access to areas not infested with goats (Daly and Goriup 1987)
- constrain captured animals (Parkes et al. 1996)
- exclude goats from water points to encourage them to use other water points where they can be trapped; this will also force them to vacate surrounding lands and reduce their impacts at these areas, and
- exclude goats from areas where vegetation can regenerate and a seed bank can develop.

Goats respect electric fences, particularly once they have encountered them. Agriculture Western Australia has experimented with electric fence designs to enclose trained goats at a cost of $670 per kilometre for material for a five-wire fence, plus approximately $800 per kilometre in construction costs. Six and seven-wire fences have also been successfully used, at a cost of approximately $1600 per kilometre. In southwest Queensland, electric fencing suitable for enclosing goats has been costed at $1800 per kilometre for materials alone at 1999 prices (Jago 1999). Where total exclusion of goats is required, adequate fences are likely to remain too expensive.

Points to consider when deciding whether to fence an area include the primary purpose of the fence, the area to be enclosed, cost and the position of watering points. Due consideration must be given to the impact of goat-proof fences on access to water by all animals, as well as on the movement of native animals.

2.4 Shooting

Aerial shooting has been successfully used to control vertebrate pest animal species in Australia, including pigs (Saunders and Bryant 1988, Hone 1990), donkeys (Choquenot 1988), water buffalo (Bayliss and Yeomans 1989) and goats (Mahood 1985, Naismith 1992, Maas and Choquenot 1995, Pople et al. 1996). This method is mostly used to control inaccessible populations, manage low-density populations or remove survivors from other control campaigns (Parkes et al. 1996, Fleming et al. 2002). It may also be the only technique for achieving broadscale reductions when the goats are not to be sold (Jago 1999).

Helicopters are commonly used as shooting platforms, with light aircraft occasionally acting as spotters. This method is expensive, and additional costs include skilled labour, ammunition and ground support. However, aerial shooting allows difficult terrain to be covered quickly and is a more effective method of quickly reducing unmanaged goat populations, giving culling rates far in excess of other control methods (Lim et al. 1992). Effectiveness has been estimated at 45–99 per cent in arid and semiarid areas (Parkes et al. 1996). The costs of this technique vary greatly, but tend to rise exponentially with decreasing goat density (Parkes 1993, Maas and Choquenot 1995). Bayne et al (2000) found that the effectiveness of this technique also declines if the goats have prior experience of aerial shooting, but effectiveness increases if ground spotters are used.

Ground-based shooting is not commonly used as a control strategy for unmanaged goats in rangeland areas of Australia because it is labour intensive and can be inefficient if there is a large number of goats over large areas, or if climatic conditions are unfavourable. It is best suited to accessible areas, and most effective if used in conjunction with other control methods, such as mustering or trapping. Volunteer shooters were successfully used for ground shooting as part of the control methods used within operation *Bounceback 2000* in South Australia. The success with volunteer shooters in this case was achieved by having well-defined objectives and coordinating the volunteers to maximise efficiency and efficacy. Ground-based shooting can be used to target individual goats if necessary. Skilled operators are required to ensure that this is done humanely.

2.5 Judas goat

This technique involves exploiting the sociability of goats. A radio or global positioning system (GPS) collar is attached to a goat, the goat is released in the expectation that it will join up with other goats and is tracked along with the herd it has joined. Judas goats are generally used where population density is low and herds are small or hard to find, to locate survivors of other control campaigns (Parkes et al. 1996) and to monitor areas thought to be free of goats (Taylor and Katahira 1988).

The TAP for goats in Tasmania (developed by the Tasmanian Parks and Wildlife Service) advocates this technique, as unmanaged goats in Tasmania occur in small isolated groups in terrain that is difficult to access (Gaffney and Atkinson 1995). However, this technique is expensive because it requires specialised equipment and skilled staff, and is warranted only in areas where goat densities need to be extremely low to protect threatened species, or where eradication of goats is a feasible option.

2.6 Fertility control

Fertility control of wild animals is still at the experimental development stage. In practice, fertility control of wild vertebrates has been achieved on only a limited scale using expensive, labour-intensive methods (Bomford 1990). It has not been successfully applied to a free-ranging population of wild vertebrates over a large area, nor has it been attempted as a method of reducing the impacts of land degradation or competition on an endangered or vulnerable species or ecological community.

Fertility control methods include hormone treatment and the use of abortifacients. The use of contraceptive control through hormone treatment is not considered a viable option for controlling unmanaged goat populations because there is no practical way to ensure effective treatment of unrestrained animals.

An alternative technique has been proposed, based on developing sterility through an autoimmune response to reproductive proteins or hormones (immunocontraception). This technique has the potential to provide a target-specific form of fertility control that can be used on wild populations. Tyndale-Biscoe (1994) argued that if immunocontraceptive technology can be made to work, it may provide a cheap, easily disseminated method for reducing fertility and populations of some pest species on a continental scale. A major benefit of immunocontraceptive techniques is that they can be species specific and are humane. However, this is not considered an appropriate management tool due to the impact it would have on the goat industry.

On pastoral properties where unmanaged goats can be effectively trapped and mustered regularly, normal livestock management procedures involving mechanical and surgical sterilisation may be viable options to regulate breeding.

2.7 Poisoning

The only poison that has been trialled for goat control in Australia is 1080 (sodium fluoroacetate), which was added to water supplies under strict regulation in Western Australia (Norbury 1993). The main risk with this technique is consumption of baits by non-target species, both native and non-native. Reducing the risk to non-target species relies on exploiting differences in goat behaviour, ecology and tolerance of the poison (Daly and Goriup 1987).

In New Zealand, two baiting techniques have been reported: pelletised grain bait which was ineffective due to goats' aversion to eating food off the ground (Forsyth and Parkes 1995), and foliage baiting, which works well in situations where only baited preferred food plants are accessible (Parkes 1983). However, in Australian conditions, goats do not have a highly preferred food plant, so the risk to non-target species is high (Parkes et al. 1996) and foliage baiting is illegal in all Australian states and territories.

Largely due to the growing commercial goat industry, poisoning is no longer considered a viable means of controlling unmanaged goats in Australia.

2.8 Biological control

Control of unmanaged goats using a pathogen may be possible in theory, but currently none is known to be virulent, humane, specific to goats and non-transferable to other species. The potential risks to both the domestic goat industry and other livestock industries from using a pathogen are too high to warrant any research on this approach. Another disadvantage is that animals are likely to develop resistance to the pathogen and such resistance will eventually spread through the species.

Unmanaged goats do not generally occur where there are uncontrolled populations of dingoes (Parkes et al. 1996). One goat population on Townshend Island (Queensland) was successfully controlled by releasing dingoes onto the island (Allen and Lee 1995). However, dingoes are not appropriate as a 'biological control' in pastoral areas, where most unmanaged goats occur, because dingo predation is not a target-specific control measure.

3. Factors affecting control of unmanaged goats

This section discusses factors that can affect the control of goats. The issues covered are commercial interests, legal status, cost efficiency, animal welfare, water management, interaction with other herbivores and cultural issues.

3.1 Commercial interests

Commercial interest in goats in Australia is in the domestic goat and wild harvest industries. For the purposes of the TAP, the term ‘wild harvest’ refers to both field shot animals and live captured animals that are immediately shipped off the property. Farmed or domestic animals are identified as being both bred and maintained in an enclosed system. Goats are identified as ranched or ‘managed’ animals if they are captured live and held on the property within goat-proof yards to adjust to captive conditions, and maintained to match market demand and supply.

Since commercial harvesting of unmanaged goats can reduce goat density, it has the potential to contribute to conservation objectives (Choquenot et al. 1995). The harvesting of unmanaged goats may reduce the costs of control, but can also lead to less effective control. In addition, the domestic goat industry provides a potential source of new unmanaged goat populations or of animals that can reinfest controlled areas if domestic stock is not adequately managed. The risks associated with the domestic goat and wild harvest industries can be estimated and are amenable to management through appropriate actions. Particularly during periods of high goat prices, goats are valued by land managers as a harvestable resource, and there is an incentive to prevent their escape. This plan is supportive of primary producers managing rangeland goats on their land for production while sustaining biodiversity values.

Effective management of domestic goats depends on having adequate fencing, and a maintenance regime to ensure that the fences are not breached. Domestic goat facilities operating near environmentally sensitive areas or areas that could act as refuges for escapees (e.g. broken ranges, which are difficult to access) should be assessed for risk. The level of security required to keep the goats on the property should be determined by the level of risk posed by any potential escape. Currently, no state or territory has provision for such an assessment process.

Commercial use of goats can involve using field shot animals to supply the game meat market, or live animals for live export trade or to supply abattoirs producing meat for the chilled or frozen meat market. In 2001–03 an estimated 1 million goats were harvested annually in Australia, with most being slaughtered in Australia (Parkes and Forsyth 2004). The domestic goat industry is partly supplemented with breeding stock derived from live-captured unmanaged animals. In 1998–99, the most recent years for which figures are available, there were 200 000 domestic goats (Parkes and Forsyth 2004).

The presence of unmanaged goats is generally seen as incompatible with the management of reserve areas for the conservation of biodiversity and the maintenance of normal ecosystem functioning. In reserve areas, the desired management outcome is to reduce unmanaged goat numbers to a level at which they have no significant impact on these values.

A regional approach to controlling unmanaged goats would clarify the management aims for particular regions and enable land managers to coordinate their actions. It would also assist in establishing regional conservation priorities and integrating management of unmanaged goats across all land tenures. Plans of this type have been established for kangaroo species where a similar situation exists, namely, to mitigate damage caused by the species and to manage them as a sustainable natural resource where appropriate.

From a national perspective, the commercial harvesting of unmanaged goats is not sufficient to control the

population due to goat population dynamics and the fact that the industry cannot match market demand due to the variability of, for instance, the supply of animals. Nevertheless, local control may be possible through commercial harvesting where access to markets, and adequate prices, facilitate the reduction of unmanaged goat numbers to very low levels.

Forsyth and Parkes (2004) reviewed the influences on unmanaged goat harvesting in Australia and found that harvesting these goats is considerably price-sensitive. They suggested that the off-take of unmanaged goats could be increased through:

- subsidies of harvest costs (approximately $5 per goat; Parkes and Forsyth 2004)
- subsidies of processing costs (approximately $18 per goat; Parkes and Forsyth 2004)
- provision of access to land and water sources to encourage competition, and
- enforcement of pest control and stocking rate regulations.

3.2 Legal status

The legal status and definition of unmanaged goats differs across the various jurisdictions of Australia. In Queensland, South Australia and Western Australia, unmanaged goats are defined as 'declared pests'; in Victoria they are an 'established pest'; and in New South Wales they are defined as 'pests', 'game' or 'unprotected fauna', depending on the legislation applied. According to a personal communication received by Forsyth and Parkes (2004), there is the capacity to declare unmanaged goats as pests in New South Wales. The Northern Territory and the Australian Capital Territory do not define unmanaged goats as a class and do not prescribe particular action. Tasmania does not define the status of goats, but does allow for control of unmanaged goats under management plans or control with the approval of the Chief Veterinary Officer.

3.3 Cost efficiency

One report (McLeod 2004) attempted to estimate the economic impact of the most important terrestrial vertebrate pests, including unmanaged goats. This was a conservative study and did not take into account all economic impacts. It estimated that 'feral' goats cost Australia $7.7 million per year, including sheep and cattle production loss, control cost and research cost.

The level of control is determined by the cost of control options and the funds available. Table 3.1 summarises the available data on the costs of various control techniques. The economic argument may also be balanced by the sale value of goats. Forsyth and Parkes (2004) estimate that annual off-take of 'feral' goats is approximately 1 million. Assuming a conservative carcass value of between $15 and $20, unmanaged goats can represent a net benefit to the Australian economy after the deduction of costs.

Management strategies including both aerial shooting and mustering are thought to achieve the highest population reductions for the minimum net cost (Parkes et al. 1996). In general, the cost of aerial shooting rises exponentially with decreasing animal density (Parkes 1993, Maas and Choquenot 1995). However, it is a very effective technique and can be used in all terrains, except those with heavy vegetation. Mustering does not reduce goat populations to the same extent as aerial shooting. However, this is offset by the lower cost, with cost-effectiveness depending on the price of goats at the time.

Trapping, like mustering, may make a profit due to the sale of captured animals, but can only be used during dry times in places where access to water can be controlled. The Judas goat technique is expensive and is only appropriate where protection of native species and ecological communities are achievable only with extremely low goat densities. Ground-based shooting is not appropriate as the primary means of control in a pastoral setting because of high labour costs, but may be a useful supplement as a commercial wild harvest

for game meat or hides. In densely vegetated areas, such as Tasmania's forests, it is the only available technique.

3.4 Animal welfare concerns

There are no nationally binding guidelines on the transportation and destruction of unmanaged goats (Bellchambers 2004), although handling practices are covered under state legislation on cruelty to animals.

Consultation with animal welfare agencies, such as the Royal Society for the Prevention of Cruelty to Animals, has been facilitated through recent developments; for example, the discussion paper *A national approach towards humane vertebrate pest control* (HVPC Working Group 2004).

Codes of practice for the welfare of feral livestock (SCA 1995) in general and for the goat in particular (SCA 1991) have been developed through the Primary Industries Standing Committee. States can either adopt these guides (as Western Australia has done) or use them to develop their own codes.

Table 3.1 Summary of the expenditure for various goat control techniques

Technique	Cost	Reference
Overall control costs for Australia	$2 million (per year)	McLeod (2004)
Estimated total labour cost for Australia	$0.7 million to $0.9 million (1998–2003)	Reddiex and Forsyth (2004)
Aerial shooting (Coolah Tops National Parks, 1997–2002)	$13.83 to $30.47 (per goat)	Fleming et al. (2002)
Mustering (Coolah Tops National Parks, 1997–2002)	$20.34 to $21.05 (per goat)	Fleming et al. (2002)
Self-mustering trap yards	$1000 to $5000 (per yard)	Bellchambers (2004) (quoting figures from previous studies)
Ground shooting	$774 (per goat)	Edwards et al. (1994)
Judas goat	$70 (per goat)	Henzell (1992b) (theoretical calculation)

The Department of the Environment and Heritage (now the Department of Environment, Water, Heritage and the Arts) commissioned the development of codes of practice and standard operating procedures (SOPs) for the humane capture, handling and destruction of feral animals. However, the codes are non-binding. The *Model code of practice for the humane control of feral goats* (Sharp and Saunders 2004a) provides information and recommendations to vertebrate pest managers responsible for the control of feral goats, including advice on how to choose the most humane, target-specific, cost-effective and efficacious control techniques.

The SOPs for goats include information about ground shooting (Sharp and Saunders 2004b), aerial shooting (Sharp and Saunders 2004c), mustering (Sharp and Saunders 2004d), trapping (Sharp and Saunders 2004e) and the use of Judas goats to locate feral goats (Sharp and Saunders 2004f). Each SOP provides information about the appropriate application of the method, animal welfare considerations, health and safety considerations, the equipment required and procedures to guide managers.

Several of these documents require updating in the context of an expanding commercial goat industry.

The most humane, effective and appropriate technique for control of unmanaged goats should be chosen to minimise suffering to the goats, and minimise harm and suffering to non-target animals, people and the broader environment (Sharp and Saunders 2004a). Sufficient resources and training must be available to implement the technique, and regular monitoring and improvement of codes of practice should occur.

Exclusion fencing is regarded as a humane and non-lethal control method, but fencing may restrict access to water by non-target species, alter behaviour patterns, cause entanglement and electrocution, and in a bushfire can stop animals from escaping. Judas goats may suffer pain and injury during capture, handling, restraint and repeated isolation from other goats.

To minimise harm and suffering, shooting must be carried out by skilled shooters, and wounded animals killed quickly and humanely. Traps must be inspected at least once daily, and goats and non-target animals provided with water, food and shelter, especially during extreme weather. If possible, traps should be designed such that non-target species can free themselves. Transport and handling should be minimised with all control techniques (Sharp and Saunders 2004a).

Techniques that are considered unsuitable on animal welfare grounds are denial of water as a means of killing animals, and trapping without prompt destruction or removal (Peters 1992). To ensure the most humane methods are used, animal welfare agencies should be consulted and involved in the development of plans for controlling unmanaged goats.

3.5 Water management

Artificial watering points in the arid and semiarid rangelands of Australia are rarely more than 10 kilometres apart (James et al. 1997). This water benefits all large herbivores, allowing them to survive in habitats that would not otherwise be suitable (Parkes et al. 1996). This has led to a much greater total grazing pressure, which has irrevocably changed the character of the landscape (James et al. 1997). Landsberg et al. (1997) found that many native species are therefore disadvantaged by water provision and recommended the closure of artificial waters. Artificial water points may be closed in conservation areas after unwanted herbivores have been removed by humane methods (Parkes et al. 1996).

While the permanent closure of artificial water points may be an option within reserves, it is not an option on land managed for livestock production. Waste minimisation and the effective management of livestock and grazing pressure should be the priority outside reserves.

3.6 Interaction with other herbivores

The presence of too many herbivores in an area leads to overgrazing and land degradation. Domestic livestock numbers can be actively controlled by land managers, but non-domestic herbivores (e.g. unmanaged goats, rabbits, kangaroos) may contribute significantly to total grazing pressure and are not as easy to control. These species need to be considered when determining total stocking rates on an area as their numbers, combined with domestic livestock numbers, may exceed the safe stocking rates for the land, particularly during drought, because of competition for declining food and water resources. Goats are extremely hardy under drought conditions and contribute significantly to land degradation.

Goats are generalist herbivores, so according to Parkes et al. (1996), the contribution of unmanaged goats to total grazing pressure should be assessed by estimating the net annual above-ground productivity of all vegetation eaten. Using this method, the authors found that goats at average densities of two goats per square kilometre consume 0.73 tonnes per year of dry matter. By comparison, rabbits at average densities of 300 per square kilometre were estimated to consume 10 tonnes per year of dry matter (Newsome 1993). However, this estimate was made before the release of the rabbit calicivirus, when average rabbit densities and consumption were many times greater then than they are now. The current impact of goat grazing is not known but, because goats are generalist herbivores, their impacts may be greater than other herbivores during periods
of drought.

Decisions about the effective allocation of resources to control unmanaged herbivores in an area require a more detailed understanding of the interactions between the individual species. Numbers of goats and numbers and types of other herbivores need to be taken into account, as well as prevailing climatic conditions.

3.7 Cultural issues

The cultural value placed on unmanaged goats varies according to the observer's own value system. Australia's unique fauna and flora is widely valued by society and many perceive unmanaged goats to be a threat to the native fauna and flora. Some, however, may see them as a resource to be maintained, waiting for an opportunity to make use of at an appropriate time.

Some Indigenous Australians recognise introduced animals as part of the landscape, seeing them as newcomers rather than as undesirable alien species (Rose 1995). Among the Indigenous community, there are divergent views on unmanaged goats. For example, although many Indigenous people hunt these animals for food or recreation, others participate in commercial harvesting of unmanaged goats, in capacities as either landowners or contractors.

An important component of any control program is consideration of the differing cultural values attached to domestic and unmanaged goats.

4. Developing a national approach to control unmanaged goats

This section looks at the different aspects involved in developing a national approach to the control of unmanaged goats in Australia. It covers planning, strategies for allocating resources and identifying priority areas for action.

4.1 Planning for nationally coordinated action

There are many stakeholders involved in the control of unmanaged goats in Australia. State and territory agencies, commercial harvesters, landholders and land managers, local government agencies, non-government organisations and community groups all have conservation, commercial or welfare interests in the management of these goats. However, reliable data on the extent and cost of control activities is scarce.

In addition to funding control programs for unmanaged goats on its own lands, the Australian Government has provided funding to state, territory and national organisations for activities to control goats (Table 4.1). Projects have included:

- strategic planning (e.g. the commissioning of a report considering the maximisation of conservation benefits for the commercial goat industry)
- control of unmanaged goats on islands (e.g. in Tasmania and on Lord Howe Island)
- localised eradication (e.g. on Peron Peninsula), and
- regional integrated control (through *Bounceback 2000* in South Australia).

Hart (2005) recommends mapping of unmanaged goats, the distribution of species susceptible to their presence and high-risk habitats, and the production of a national overview of priority regions.

4.2 Strategies for allocating resources to control unmanaged goats

Strategies for addressing unmanaged goats will need to include localised control and eradication, sustained and intermittent control using an experimental approach and buffer zones, and regional control using an adaptive approach. In an audit of pest species control actions, 157 control actions with the aim of eradication or sustained or intermittent control of unmanaged goats occurred between 1998 and 2003 (Reddiex et al. 2004). More than 80 per cent of these actions are ongoing.

Localised control of unmanaged goats is vital in specific areas of high conservation concern, particularly around populations of threatened species. Recovery plans for a number of threatened species identify the unmanaged goat as a threat. See the *Threat abatement plan for competition and land degradation by unmanaged goats* (DEWHA 2008) for a list of threatened species affected by unmanaged goats.

Table 4.1 Australian Government projects related to controlling unmanaged goats, 2002–06

Project name	Recipient of funding
2002–03	
A project to increase understanding of feral goat, feral cat, feral rabbit, fox and feral pig control required to minimise threats to native species and ecological communities	Arthur Rylah Institute for Environmental Research
A project that improves the development of effective and humane trapping systems as a control method for feral goats in Australia	Ardeotis Biological Consultants Pty Ltd
Cost effective fencing systems to exclude feral animals from areas of high conservation value in Australia	Arthur Rylah Institute for Environmental Research
Maximising the conservation benefits of the commercial goat industry in Australia	Arthur Rylah Institute for Environmental Research
Development of a model code of practice and standard operating procedures for the humane capture, handling or destruction of feral animals in Australia	NSW Agriculture
2003–04	
A project that develops an agreed code of practice and standard operating procedures for the humane care and use of pest animals in Australia for the purposes of scientific research	NSW Agriculture
2004–05	
A project that reviews the Commonwealth Government's threat abatement plans for feral goats, feral rabbits, feral cats and the European red fox	Bureau of Rural Sciences
Introduced animals on New South Wales islands: improving Australia's ability to protect its island habitats from feral animals	NSW Department of Conservation
A report outlining Australia's past performance in invasive species prevention, detection, eradication and management	Agtrans Research
Introduced animals on Northern Territory islands: improving Australia's ability to protect its island habitats from feral animals	NT Department of Infrastructure, Planning and Environment
Introduced animals on Tasmanian islands: improving Australia's ability to protect its island habitats from feral animals	Tasmanian Department of Primary Industries, Water and Environment

2005–06	
Landscape-based optimisation of vertebrate pest management strategies	University of Canberra

NSW = New South Wales; NT = Northern Territory

Local eradication of unmanaged goats is an option for areas which meet strict criteria associated with vulnerability to, and effectiveness of, control techniques, and fertility and fecundity (see Section 2). Maintaining an area free from goats requires a sustained control operation to prevent reinvasion from surrounding areas, or the use of exclusion fences. As a strategy, local eradication is applicable to:

- islands — island size is less of a limiting factor than it was in the past due to new techniques and technology (Campbell and Donlan 2005)
- isolated small populations on the mainland, or
- small mainland sites which are surrounded by goat exclusion fences.

Where eradication is not possible, two broad strategies may be used for localised control of unmanaged goats. In sustained management, control is implemented on a continuing, regular basis. Intermittent management seeks to apply control at critical periods of the year when damage is greatest, enabling short-term control to reduce impacts to acceptable levels. Intermittent control can be useful as a temporary measure at sites where unmanaged goats are a seasonal threat (e.g. towards annual plants) or where the threat is most pronounced during adverse conditions such as drought.

To ensure efficient and effective use of resources in the maintenance of biodiversity, an experimental approach should be used to:

- determine the significance of competition and land degradation by unmanaged goats, and
- identify the level of control necessary for the recovery of threatened species.

If it is confirmed, through this approach, that unmanaged goats are a significant threat, control strategies can be properly justified and expanded. Otherwise, efforts should be directed towards other strategies to promote species recovery.

Buffer zones could be used to manage small areas, to reduce or stop continual reinvasion replacing goats removed during control operations. Development of buffer zones requires the active participation of all local stakeholders (e.g. landholders), which is more likely to occur if the benefits to all participants are clearly identified.

Regional management should focus on key broadscale approaches to unmanaged goat control and the reduction of impacts on a range of threatened species. In this way, maximum benefit can be obtained, expanding available habitat to a greater degree than with subregional approaches; however, it does require substantial investment and infrastructure.

An adaptive management approach is well suited to the regional scale because different experimental control techniques can be used within a broadly comparable area. Regional management also provides a means of integrating unmanaged goat control with other biodiversity conservation programs.

Each strategy to control unmanaged goats must be monitored for native species recovery outcomes. High numbers of goats removed does not necessarily equate to conservation benefits such as reduced competition or reduced land degradation, due to the high reproductive rates of goats. Outcomes and the

methods used need to be disseminated widely. Experimental designs that include paired treatment and non-treatment sites, goat exclosures and pre- and post-experimental monitoring to further our understanding of the benefits of controlling unmanaged goats to native species (such as that advocated by Reddiex and Forsyth 2004) should be adopted, and sufficient resources provided.

4.3 Identifying priority areas for action

The identification of species and regions that will benefit most from coordinated control activities for unmanaged goats is clearly important. Areas need to be ranked on a nationally consistent basis to ensure that decisions about funding for control activities can maximise the derived conservation benefits.

An agreed national methodology for ranking areas should cover protecting and facilitating the expansion of existing populations of threatened species, and preparing areas for translocation. A priority ranking system to weight areas according to risk and the possibility of reducing risk from unmanaged goat activity should be developed. Guidance on priority ranking systems can be found for mammalian pests in New Zealand (Parkes and Nugent 1995), the fox (NSW NPWS 2001), feral cats (Dickman 1996) and for pest animals in general (Braysher and Saunders 2003).

Parkes et al. (1996) describe a priority ranking system developed in New Zealand for investment in goat control. This is a complex process that involves scoring native species in an area according to their conservation value and then weighting these scores for the threat posed to the species. Using the New Zealand system as a guide, procedures for prioritising areas for controlling unmanaged goats in Australia will be refined. Accordingly, priorities for goat control for biodiversity conservation should be guided by:

- the degree of threat that goats pose to the survival of a species or ecological community
- the potential of the species or ecological community to recover
- the number of threatened species likely to benefit from control in a locality, and
- the cost-efficiency and likely effectiveness of goat control in each area, including the availability of sufficient resources for control that is sustained and logistically possible.

Appendix A: Threat abatement plans and the EPBC Act

Extracts from the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and EPBC Regulations 2000 relating to the requirements for threat abatement plans.

Section 271 Content of threat abatement plans

(1)
A threat abatement plan must provide for the research, management and other actions necessary to reduce the key threatening process concerned to an acceptable level in order to maximise the chances of the long-term survival in nature of native species and ecological communities affected by the process.

(2) In particular, a threat abatement plan must:

(a) state the objectives to be achieved; and

(b) state the criteria against which achievement of the objectives is to be measured; and

(c) specify the actions needed to achieve the objectives; and

(g) meet prescribed criteria (if any) and contain provisions of a prescribed kind (if any).

(3) In making a threat abatement plan, regard must be had to:

(a) the objects of this Act; and

(b) the most efficient and effective use of resources that are allocated for the conservation of species and ecological communities; and

(c) minimising any significant adverse social and economic impacts consistently with the principles of ecologically sustainable development; and

(d) meeting Australia's obligations under international agreements between Australia and one or more countries relevant to the species or ecological community threatened by the key threatening process that is the subject of the plan; and

(e) the role and interests of indigenous people in the conservation of Australia's biodiversity.

(4) A threat abatement plan may:

(a) state the estimated duration and cost of the threat abatement process; and

(b) identify organisations or persons who will be involved in evaluating the performance of the threat abatement plan; and

(c) specify any major ecological matters (other than the species or communities threatened by the key threatening process that is the subject of the plan) that will be affected by the plan's implementation.

(5) Subsection (4) does not limit the matters that a threat abatement plan may include.

Section 274 Scientific Committee to advise on plans

(1) The Minister must obtain and consider the advice of the Scientific Committee on:

(a) the content of recovery and threat abatement plans; and

(b) the times within which, and the order in which, such plans should be made.

(2) In giving advice about a recovery plan, the Scientific Committee must take into account the following matters:

(a) the degree of threat to the survival in nature of the species or ecological community in question;

(b) the potential for the species or community to recover;

(c) the genetic distinctiveness of the species or community;

(d) the importance of the species or community to the ecosystem;

(e) the value to humanity of the species or community;

(f) the efficient and effective use of the resources allocated to the conservation of species and ecological communities.

(3) In giving advice about a threat abatement plan, the Scientific Committee must take into account the following matters:

(a) the degree of threat that the key threatening process in question poses to the survival in nature of species and ecological communities;

(b) the potential of species and ecological communities so threatened to recover;

(c) the efficient and effective use of the resources allocated to the conservation of species and ecological communities.

Section 279 Variation of plans by the Minister

(1) The Minister may, at any time, review a recovery plan or threat abatement plan that has been made or adopted under this Subdivision and consider whether a variation of it is necessary.

(2) Each plan must be reviewed by the Minister at intervals not longer than 5 years.

(3) If the Minister considers that a variation of a plan is necessary, the Minister may, subject to subsections (4), (5), (6) and (7), vary the plan.

(4) The Minister must not vary a plan, unless the plan, as so varied, continues to meet the requirements of section 270 or 271, as the case requires.

(5) Before varying a plan, the Minister must obtain and consider advice from the Scientific Committee on the content of the variation.

(6) If the Minister has made a plan jointly with, or adopted a plan that has been made by, a State or self-governing Territory, or an agency of a State or self-governing Territory, the Minister must seek the co-operation of that State or Territory, or that agency, with a view to varying the plan.

(7) Sections 275, 276 and 278 apply to the variation of a plan in the same way that those sections apply to the making of a recovery plan or threat abatement plan.

Environment Protection and Biodiversity Conservation Regulations 2000

REG 7.12 Content of threat abatement plans

For paragraph 271 (2) (g) of the Act, a threat abatement plan must state:

(a) any of the following that may be adversely affected by the key threatening process concerned:

(i) listed threatened species or listed threatened ecological communities;

(ii) areas of habitat listed in the register of critical habitat kept under section 207A of the Act;

(iii) any other native species or ecological community that is likely to become threatened if the process continues; and

(b) in what areas the actions specified in the plan most need to be taken for threat abatement.

Glossary

Abortifacient	A substance that induces abortion.
Arid (zone)	The arid and semiarid lands are those remote and sparsely populated areas of inland Australia, defined by the presence of desert vegetation and land forms as well as by low rainfall. They are bound by median annual rainfalls of about 250 mm in the south but up to 800 mm in the north and about 500 mm in the east (Beeton et al. 2006).
Biodiversity	Variability among living organisms from all sources (including terrestrial, marine and other ecosystems and ecological complexes of which they are part), which includes diversity within species and between species and diversity of ecosystems (Beeton et al. 2006).\
Biodiversity conservation	The protection, maintenance, management, sustainable use, restoration and enhancement of the natural environment (Beeton et al. 2006).
Buffer zone	An area that keeps two or more areas distant from one another.
Critically endangered	Under the EPBC Act, a native species is eligible to be included in the critically endangered category at a particular time if, at that time, it is facing an extremely high risk of extinction in the wild in the immediate future, as determined in accordance with the prescribed criteria.
Diurnal	Active by day.
Endangered	Under the EPBC Act, a native species is eligible to be included in the endangered category at a particular time if, at that time, (a) it is not critically endangered; and (b) it is facing a very high risk of extinction in the wild in the near future, as determined in accordance with the prescribed criteria.
Eradication	Application of measures to eliminate an invasive alien species from a defined area.
Exclosure	Area fenced to keep out unwanted animals.
Fecundity	Potential rate at which an organism reproduces.

Feral	An introduced animal, formerly in domestication, with an established self-supporting population in the wild.
Immunocontraception	The stimulation of the immune responses (antibody production and cell-mediated immunity) in the target animal against its own reproductive hormones, gamete proteins or another protein essential to reproduction, to induce sterility (Saunders and McLeod 2007).
Key threatening process	Under the EPBC Act, a process that threatens or may threaten the survival, abundance or evolutionary development of a native species or ecological community.
Pest animal or species	Any non-human species of animal that causes trouble locally or over a wide area, to one or more persons, either by being a health hazard, a general nuisance, or by causing damage to agriculture, wild ecosystems or natural resources.
Recovery plan	Under the EPBC Act, a document setting out the research and management actions necessary to stop the decline of, and support the recovery of, listed threatened species or threatened ecological communities.
Semiarid	Regions that receive low annual rainfall (250–500 mm) and generally have scrub or short-grass vegetation.
Threat abatement plan	Under the EPBC Act, a plan providing for the research, management, and any other actions necessary to reduce the impact of a listed key threatening process on impacted species and ecological communities.
Threatened species	Refers to the Australian Government list of threatened native species divided into the following categories as per the EPBC Act: critically endangered, endangered, vulnerable, conservation dependent.
Unmanaged goats	Goats that are free-living and not subject to livestock husbandry but may be ‘owned’ in the sense that access for harvesting or control is determined by the owner or occupier of the land. This is in contrast to ‘managed’ goats, which are those held under some combination of animal husbandry methods (such as being owned, identified, restrained, managed for population structure and density, and receive welfare). Some goats, however, have one or more of the characteristics of managed goats, but in all other respects are indistinguishable from unmanaged animals with no husbandry.

Vulnerable	Under the EPBC Act, a native species is eligible to be included in the vulnerable category at a particular time if, at that time, (a) it is not critically endangered or endangered; and (b) it is facing a high risk of extinction in the wild in the medium-term future, as determined in accordance with the prescribed criteria.
Wild	Not domesticated or cultivated, but including escapees from domestication or cultivation.

Acronyms and abbreviations

DEWHA	Department of the Environment, Water, Heritage and the Arts
EPBC Act	the Commonwealth Environment Protection and Biodiversity Conservation Act 1999
SOP	standard operating procedure
TAP	threat abatement plan

References

Allen LR and Lee JM (1995). *The management of feral goat impact on Townsend Island*, progress report to the Department of Defence, Queensland Department of Lands.

Bayliss P and Yeomans K (1989). Distribution and abundance of feral livestock in the 'Top End' of the Northern Territory (1985–86), and their relation to population control. *Australian Wildlife Research* 16:651–676.

Bayne P, Harden R, Pines K and Taylor U (2000). Controlling feral goats by shooting from a helicopter with and without the assistance of ground-based spotters. *Wildlife Research* 27:517–523.

Bayne PA, Harden R and Davies I (2004). Feral goats (*Capra hircus* L.) in the Macleay River gorge system, north-eastern New South Wales, Australia, I. Impacts on soil erosion. *Wildlife Research* 31(5):519–525.

Beeton R, Buckley K, Jones G, Morgan D, Reichelt R and Trewin D (2006). *Australia state of the environment 2006,* independent report to the Australian Government Minister for the Environment and Heritage, Australian Government Department of the Environment and Heritage, Canberra.

Bellchambers K (2004). *Improving the development of effective and humane trapping systems as a control method for feral goats in Australia*, Australian Government Department of the Environment and Heritage, Canberra.
http://www.environment.gov.au/biodiversity/invasive/publications/goat-trapping/index.html (Accessed December 2007)

Bomford M (1990). *A role for fertility control in wildlife management?* Bureau of Rural Resources, Bulletin 7, Canberra.

Bomford M and Hart Q (2002). Non-indigenous vertebrates in Australia. In: *Biological invasions: economic and environmental costs of alien plant, animal, and microbe species*, Pimentel D (ed), CRC Press, London, England, 25–44.

Braysher M and Saunders G (2003). *PESTPLAN: a guide to setting priorities and developing a management plan for pest animals*, Natural Heritage Trust, Canberra.

Campbell K and Donlan CJ (2005). Feral goat eradications on islands. *Conservation Biology* 19(5):1362.

Choquenot D (1988). *Feral donkeys in northern Australia: population dynamics and cost of control,* Canberra College of Advanced Education, Canberra.

Choquenot D, O'Brien P and Hone J (1995). Commercial use of pests: can it contribute to conservation objectives? In: *Conservation through sustainable use of wildlife*, Grigg GC, Hale PT and Lunney D (eds), Centre for Conservation Biology, University of Queensland, 251–258.

Coblentz BE (1977). Some range relationships of feral goats on Santa Catalina Island, California. *Journal of Range Management* 30(6):415–419.

Daly K and Goriup P (1987). *Eradication of feral goats from small islands*, report to the International Council for Bird Preservation, Cambridge, Study Report No. 17.

Dawson TJ, Denny MJS, Russell EM and Ellis B (1975). Water use and diet preferences of free ranging

kangaroos, sheep and feral goats in the Australian arid zone during summer. *Journal of Zoology* 177:1–123.

DEWHA (Department of the Environment, Water, Heritage and the Arts) (2008). *Threat abatement plan for competition and land degradation by unmanaged goats*, DEWHA, Canberra.

Dickman CR (1996). *Overview of the impact of feral cats on Australian native fauna*, report to the Australian Nature Conservation Agency, Canberra. http://www.environment.gov.au/biodiversity/invasive/publications/cat-impacts/index.html (Accessed December 2007)

Doyle PT, Egan JK and Thalen AJ (1984). Intake, digestion, and nitrogen and sulfur retention in Angora goats and Merino sheep fed herbage diets. *Australian Journal of Experimental Animal Husbandry* 24:165–169.

EA (Environment Australia) (1999). *Threat abatement plan for competition and land degradation by feral goats*, EA, Canberra.

Edwards GP, Clancy TF, Lee J and McDonnell J (1994). *Feral animal control in the rangelands*, final report to the Australia Nature Conservation Agency, Canberra.

Eldridge DJ and Greene RSB (1994). Microbiotic soil crusts: a review of their roles in soil and ecological processes in the rangelands of Australia. *Australian Journal of Soil Research* 32:389–415.

Fleming PJS (2004). Relationships between feral goats (*Capra hircus*) and domestic sheep (*Ovis aries*) with reference to exotic disease transmission. PhD thesis, Applied Ecology Research Group, University of Canberra.

Fleming P, Tracey J, Jones G, England K, Leeson M and Martin M (2002). *The costs of methods for reducing feral goat abundance at a high density site*, Balogh S (ed), NSW Agriculture, Orange, 93–96.

Forsyth DM and Parkes JP (1995). Suitability of aerially sown artificial baits as a technique for poisoning feral goats. *New Zealand Journal of Ecology* 19:73–76.

Forsyth DM and Parkes JP (2004). *Maximising the conservation benefits of the commercial goat industry in Australia*, Australian Government Department of the Environment and Heritage, Canberra. http://www.environment.gov.au/biodiversity/invasive/publications/commercial-goat/index.html (Accessed December 2007)

Gaffney RF and Atkinson GC (1995). *Feral goat threat abatement plan for Tasmania: management phase*, Parks and Wildlife Service, Department of Environment and Land Management, Tasmania.

Greene RSB, Nettleton WD, Chartres CJ, Leys JF and Cunningham RB (1998). Runoff and micromorphological properties of a grazed haplargid, near Cobar, NSW, Australia. *Australian Journal of Soil Research* 36:87–108.

Harrington GN (1979). The effects of feral goats and sheep on the shrub populations in a semi-arid woodland. *Australian Rangelands Journal* 1:334–345.

Harrington GN (1982). The feral goat. In: *Goats for meat and fibre in Australia*, Holst PJ (ed), CSIRO, Canberra, 3–73.

Harrington GN (1986). Herbivore diet in a semi-arid *Eucalyptus populnea* woodland. 2. Feral goats. *Australian Journal of Experimental Agriculture* 26:423–429.

Hart Q (2005). *A review of the Commonwealth Government's threat abatement plans for feral goats, feral rabbits, feral cats and the European red fox*, final report for the Australian Government Department of the Environment and Heritage, Bureau of Rural Sciences, Canberra.

Henzell RP (1984). *Methods of controlling feral goats,* South Australian Department of Agriculture, South Australia, Fact Sheet No. 20/84.

Henzell RP (1992a). The ecology of feral goats. In: *Proceedings of the national workshop on feral goat management*, Freudenberger D (ed), Bureau of Resource Sciences, Canberra, 13–20.

Henzell RP (1992b). Summary of goat biology and environmental impacts — implications for eradication. In: *Feral goat seminar proceedings*, Best LW (ed), South Australian Department of Environment and Planning, Adelaide.

Henzell R (1993). The ecology of feral goats. In: *Planning for action*, Freudenberger D (ed), Proceedings of the National Workshop on Feral Goat Management, Bureau of Resource Sciences, Canberra, 9–16.

Henzell R (2000). Goat *Capra hircus* Linnaeus 1758. In: *The mammals of Australia*, Strahan R (ed), Reed Books, Sydney, 728–730.

Hone J (1990). Predator-prey theory and feral pig control, with emphasis on evaluation of shooting from a helicopter. *Australian Wildlife Research* 17:123–130.

HVPC Working Group (Humane Vertebrate Pest Control Working Group) (2004). A national approach towards humane vertebrate pest control. Discussion paper arising from the proceedings of an RSPCA Australia, AWC and VPC joint workshop, August 4–5, Melbourne, RSPCA Australia, Canberra.

Jago B (1999). *Feral goat* (Capra hircus) *in Queensland*, Pest Status Review Series — Land Protection, Queensland Department of Natural Resources and Mines, Queensland.

James C, Landsberg J and Morton S (1997). Provision of watering points in Australian rangelands: a literature review of effects on biota. In: *The effects of artificial sources of water on rangeland biodiversity*, Landsberg J, James C, Morton S, Hobbs TJ, Stol J, Drew A and Tongway H (eds), Department of Environment, Sport and Territories, Canberra.

Kinloch JE and Friedel MH (2005). Soil seed reserves in arid grazing lands of central Australia. Part 1: seed bank and vegetation dynamics. *Journal of Arid Environments* 60(1):133–161.

Landsberg JL, James CD, Morton SR, Hobbs TJ, Stol J, Drew A and Tongway H (1997). *The effects of artificial sources of water on rangeland biodiversity*, final report to the Department of Environment, Sport and Territories, CSIRO Division of Wildlife and Ecology, Canberra.

Letnic M (2004). Cattle grazing in a hummock grassland regenerating after fire: the short-term effects of cattle exclusion on vegetation in south-western Queensland. *The Rangeland Journal* 26(1):34–48.

Lim L, Sheppard N, Smith P and Smith J (1992). *The biology and management of the yellow-footed rock-wallabies,* Petrogale xanthopus*, in New South Wales*, New South Wales National Parks and Wildlife Service Species Management Report 10, Sydney.

Ludwig JA, Tongway DJ, Freudenberger D, Noble J and Hodgkinson K (eds) (1997). *Landscape ecology: function and management: principles from Australia's rangelands,* CSIRO Publishing, Melbourne, Australia.

Maas S and Choquenot D (1995). *Feral goats in outcrop areas of the semi-arid rangelands: aerial survey techniques and the cost of helicopter shooting*, final report to the Bureau of Resource Sciences, Canberra.

Mahood IT (1985). Some aspects of ecology and the control of feral goats (*Capra hircus* L.) in western New South Wales. MSc thesis, Macquarie University.

McLeod R (2004). *Counting the cost: impact of invasive animals in Australia, 2004*, Cooperative Research

Centre for Pest Animal Control, Canberra. http://www.invasiveanimals.com/images/pdfs/CountingTheCost.pdf (Accessed December 2007)

Mills AJ, Cowling RM, Fey MV, Kerley GIH, Donaldson JS, Lechmere-Oertel RG, Sigwela AM, Skowno AL and Rundel P (2005). Effects of goat pastoralism on ecosystem carbon storage in semiarid thicket, Eastern Cape, South Africa. *Austral Ecology* 30(7):797–804.

Naismith T (1992). Feral goat control in national parks in the Flinders and Gammon Ranges. In: *Feral goat seminar proceedings*, Best LW (ed), South Australian Department of Environment and Planning, Adelaide 32–33.

Newsome AE (1993). Ecological interactions. In: *Australian rabbit control conference*, Cooke BD (ed), Glenside, Adelaide, South Australia, 2–3 April, 1993, Anti-rabbit Research Foundation of Australia, Adelaide, 23–25.

Norbury G (1993). *The proposed use of 1080 to control feral goats in Western Australia, Appendix 3*, Public Environmental Review Environment Protection Authority, Agricultural Protection Board of Western Australia Assessment No. 752.

NSW NWPS (New South Wales National Parks and Wildlife Service) (2001). *Threat abatement plan for predation by the red fox* (*Vulpes vulpes*), NSW NPWS, Hurstville.

O'Brien PH (1984). Feral goat home range: influence of social class and environmental factors. *Applied Animal Behaviour Science* 12:373–385.

Parkes JP (1983). Control of feral goats by poisoning with compound 1080 on natural vegetation baits and by shooting. *New Zealand Journal of Forestry Science* 13:266–274.

Parkes JP (1990). Feral goat control in New Zealand. *Biological Conservation* 54:335–348.

Parkes JP (1993). Feral goats: designing solutions for a designer pest. *New Zealand Journal of Ecology* 17:71–83.

Parkes J and Forsyth D (2004). *Predicting the size of the commercial harvest of feral goats in Australia*, Australasian Wildlife Management Society 17th Scientific Meeting and AGM, Kingscote, Kangaroo Island, South Australia, 29 November to 2 December 2004, Australasian Wildlife Management Society, Canberra.

Parkes JP and Nugent G (1995). *Integrating control of mammalian pests to protect conservation values in New Zealand*, Manaaki Whenua–Landcare Research Christchurch, New Zealand, Landcare Research Contract Report LC 9495/104.

Parkes J, Henzell R and Pickles G (1996). *Managing vertebrate pests: feral goats*, Australian Government Publishing Service, Canberra.

Peters M (1992). Animal welfare considerations and goat control. In: *Feral goat seminar proceedings*, Best LW (ed), South Australian Department of Environment and Planning, Adelaide.

Pople AR, Clancy TF and Thompson JA (1996). *Control and monitoring of feral goats in central-western Queensland*, report to the Australian Nature Conservation Agency, Canberra.

Reddiex B, Forsyth DM, McDonald-Madden E, Einoder LD, Griffioen PA, Chick RR and Robley AJ (2004). *Review of existing red fox, wild dog, feral cat, feral rabbit, feral pig, and feral goat control in Australia. I Audit,* Arthur Rylah Institute for Environmental Research, Department of Sustainability and Environment, Melbourne. http://www.environment.gov.au/biodiversity/invasive/publications/feral-audit/summary.html (Accessed

December 2007)

Reddiex B and Forsyth DM (2004). *Review of existing red fox, feral cat, feral rabbit, feral pig and feral goat control in Australia. II Information Gaps*, Arthur Rylah Institute for Environmental Research, Department of Sustainability and Environment, Melbourne. http://www.environment.gov.au/biodiversity/invasive/publications/information-gaps/pubs/information-gaps-final.pdf (Accessed December 2007)

Rose B (1995). *Land management issues: attitudes and perceptions amongst Aboriginal people of Central Australia*, Central Land Council, Alice Springs.

Saunders G and Bryant H (1988). The evaluation of a feral pig eradication program during a simulated exotic disease outbreak. *Australian Wildlife Research* 15:73–81.

Saunders G and McLeod L (2007). *Improving fox management strategies in Australia*, Bureau of Rural Sciences, Canberra.

SCA (Standing Committee on Agriculture) (1991). *Model code of practice for the welfare of animals: the goat*, SCA Technical Report No. 32, CSIRO Publishing, Victoria. http://downloads.publish.csiro.au/books/download.cfm?ID=368 (Accessed December 2007)

SCA (Standing Committee on Agriculture) (1995). *Model code of practice for the welfare of animals: feral livestock animals*, SCA Technical Report No. 34, CSIRO Publishing, Victoria. http://downloads.publish.csiro.au/books/download.cfm?ID=370 (Accessed December 2007)

Sharp T and Saunders G (2004a). *Model code of practice for the humane control of feral goats*, Vertebrate Pest Research Unit, Australian Government Department of the Environment and Heritage, Canberra. http://www.environment.gov.au/biodiversity/invasive/publications/humane-control/cop-feral-goats.pdf (Accessed December 2007)

Sharp T and Saunders G (2004b). *GOA001 Ground shooting of feral goats*, Vertebrate Pest Research Unit, Australian Government Department of the Environment and Heritage, Canberra. http://www.environment.gov.au/biodiversity/invasive/publications/humane-control/goa001-ground-shooting-feral-goats.pdf (Accessed December 2007)

Sharp T and Saunders G (2004c). *GOA002 Aerial shooting of feral goats*, Vertebrate Pest Research Unit, Australian Government Department of the Environment and Heritage, Canberra. http://www.environment.gov.au/biodiversity/invasive/publications/humane-control/goa002-aerial-shooting-feral-goats.pdf (Accessed December 2007)

Sharp T and Saunders G (2004d). *GOA003 Mustering of feral goats*, Vertebrate Pest Research Unit, Australian Government Department of the Environment and Heritage, Canberra. http://www.environment.gov.au/biodiversity/invasive/publications/humane-control/goa003-mustering-feral-goats.pdf (Accessed December 2007)

Sharp T and Saunders G (2004e). *GOA004 Trapping of feral goats*, Vertebrate Pest Research Unit, Australian Government Department of the Environment and Heritage, Canberra. http://www.environment.gov.au/biodiversity/invasive/publications/humane-control/goa004-trapping-feral-goats.pdf (Accessed December 2007)

Sharp T and Saunders G (2004f). *GOA005 Use of Judas goats to locate feral goats*, Vertebrate Pest Research Unit, Australian Government Department of the Environment and Heritage, Canberra. http://www.environment.gov.au/biodiversity/invasive/publications/humane-control/goa005-use-judas-

goats.pdf (Accessed December 2007)

Southwell C, Weaver K, Sheppard N and Morris P (1993). Distribution and relative abundance of feral goats in the rangelands of eastern Australia. *Rangeland Journal* 15:334–338.

Sparrow AD, Friedel MH and Tongway DJ (2003). Degradation and recovery processes in arid grazing lands of central Australia Part 3: implications at landscape scale. *Journal of Arid Environments* 55(2):349–360.

Squires VR (1980). Chemical and botanical composition of the diets of oesophageally fistulated sheep, cattle and goats in a semi-arid *Eucalyptus populnea* woodland community. *Australian Rangelands Journal* 2:94–103.

Taylor D and Katahira L (1988). Radio telemetry as an aid in eradicating remnant feral goats. *Wildlife Society Bulletin* 16:297–299.

Thompson J, Riethmuller J, Kelly D, Boyd-Law S and Miller E (1999). *Feral goat management in South-West Queensland*, final report to the Bureau of Rural Sciences, Queensland Department of Natural Resources and Mines, Brisbane.

Tiver F and Andrew MH (1997). Relative effects of herbivory by sheep, rabbits, goats and kangaroos on recruitment and regeneration of shrubs and trees in eastern South Australia. *Journal of Applied Ecology* 34:903–914.

Tyndale-Biscoe CH (1994). Virus-vectored immunocontraception of feral mammals. *Reproduction Fertility and Development* 6:281–287.

Wasson RJ and Galloway RW (1986). Sediment yield in the Barrier Range before and after European settlement. *Rangeland Journal* 8(2):79–90.

Wilson AD, Leigh LH, Hindley NL and Mulham WE (1975). Comparison of the diets of goats and sheep on a *Casuarina cristata–Heterodendrum oleifolium* woodland community in western New South Wales. *Australian Journal of Experimental Agriculture and Animal Husbandry* 15:45–53.