Australian Government
Department of the Environment

Background:

Threat abatement plan for predation, habitat degradation, competition and disease transmission by feral pigs (*Sus scrofa*)

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INTRODUCTION

In 2001 the Australian Government listed **'Predation, habitat degradation, competition and disease transmission by feral pigs (*Sus scrofa*)'** as a key threatening process under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

This listing initiated the development of the first '*Threat abatement plan for predation, habitat degradation, competition and disease transmission by feral pigs (Sus scrofa)'*, which was made in 2005.

The first threat abatement plan was reviewed in 2011. The revised threat abatement plan (2015) aims to capture scientific research and other developments that have occurred since the first plan was made, and capture changing priorities for feral pig management.

This background document to the 2015 *Threat abatement plan for predation, habitat degradation, competition and disease transmission by feral pigs (Sus scrofa)'* provides the detailed information that underpins the threat abatement plan, including biological and scientific information. Relevant extracts from the EPBC Act and EPBC Regulations related to threat abatement plans are included at Appendix A of this document.

SPECIES OVERVIEW

1. Origin and current distribution

The wild form of pig (*Sus scrofa*), also known as wild boar, is native to Eurasia. Wild pigs have been domesticated for millennia, leading to various breeds of domestic pig. Wild pigs, feral pigs and domestic pigs all belong to the same species—*Sus scrofa*—hence their ability to readily interbreed. However wild or feral pigs and domesticated pigs are sometimes differentiated as sub-species by use of the trinomial scientific names *Sus scrofa scrofa* and *Sus scrofa domestica* respectively. The species *Sus scrofa* belongs to the Suidae Family, in which there are nine species in five genera, including four other species in the *Sus* genus: *S. barbatus* (Bornean bearded pig), *S. celebensis* (Celebes or Sulawesi warty pig), *S. verrucosus* (Javan warty pig) and *S. salvanius* (pygmy hog)[*] (Choquenot et al., 1996).

Feral pigs in Australia are a result of releases and escapes of various breeds of domestic pig dating back to the late 1700's (McIlroy, 1990). The main breeds of domestic pig involved in the evolution of Australia's feral pig population are believed to be the European Berkshire and Tamworth breeds, which had already been heavily modified by cross-breeding with other breeds from China, India, Italy and Portugal (Choquenot et al., 1996). It is also believed that some populations in the Northern Territory and Queensland may have originated from *S. celebensis* imported from the historical Timor region. These animals are thought to have later interbred with pigs of domestic origin (*S. scrofa*) (Choquenot et al., 1996).

In 1990 it was estimated there were between 3.5 million and 23.5 million feral pigs in Australia, inhabiting approximately 38% of mainland Australia (Hone, 1990a). By 2008, it was estimated that feral pigs inhabited 45% (3.43 million square kilometres) of Australia (West, 2008), with much of this expansion suspected to be due to illegal releases of feral pigs.

[*] Many authorities now classify this species as *Porcula salvania* (*sensu* Funk et al., 2007)

Feral pigs occur in all states and territories, and on some large coastal islands. Figure 1 shows that feral pigs:

- are most abundant in New South Wales and Queensland
- are 'widespread' throughout New South Wales and Queensland, and are 'localised' throughout other states and territories
- are abundant in the Fitzroy River area of north-western Western Australia
- occur at low densities throughout other parts of Western Australia, South Australia and Victoria
- are present in the southeast of Tasmania and on Flinders Island
- occur throughout most of their range in Australia at 'occasional' and 'common' abundances
- are largely absent from Australia's arid and semi-arid interior (apart from parts of far-western New South Wales and south-western Queensland)
- are absent from 50% of the country and their occurrence is unknown in 5% (West, 2008).

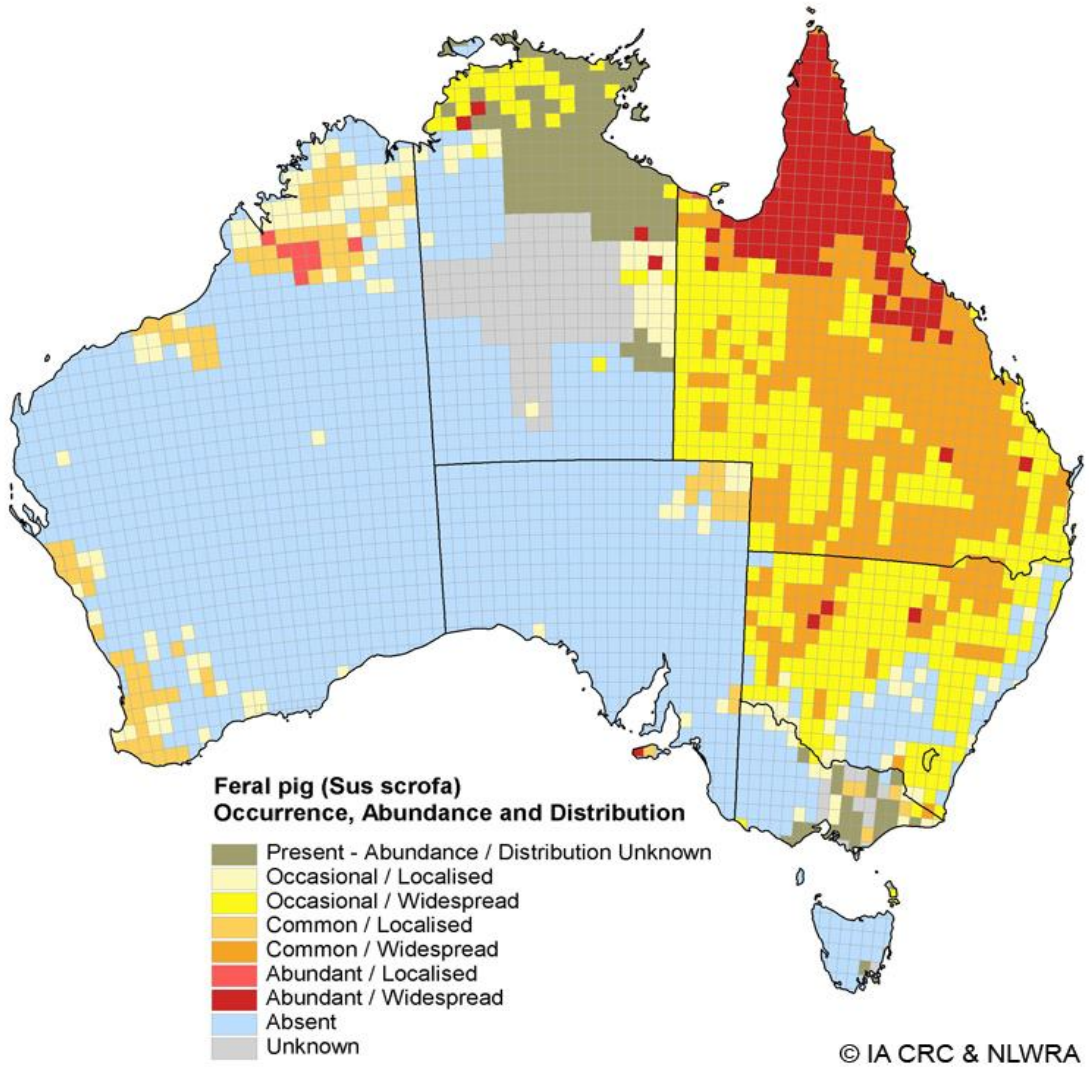

Figure 1: Map showing the occurrence, abundance and distribution of feral pigs (*Sus scrofa*) in Australia in 2006/2007 (from West, 2008). Information available for this distribution map varies in quality. A number of areas have high-quality data that are supported by expert opinion, while other areas have moderate levels of supporting information. See West (2008) for details on data quality

The range of estimates for the feral pig population in Australia varies greatly, partly because of the difficulty in estimating their numbers, but also because their populations can fluctuate widely in response to variations in environmental conditions and the availability of food and water. Extended dry periods/droughts and control programs can reduce feral pig densities to roughly half of that found under more productive conditions (Giles, 1980). However, feral pigs can increase their numbers at a rate of up to 86% a year in good seasons—a reproductive potential that is closer to rabbits than to other pests of a similar size (Choquenot et al.,1996).

Population sizes and spread have been enhanced by escapes from domestic populations and the illegal release of feral pigs for recreational hunting. Indeed, continued illegal releases of feral pigs for recreational hunting, particularly to areas in which they did not previously occur, is a major threat to effective management of feral pigs and their damage. For instance, genetic techniques have proven the relatively new feral pig populations in south-western Western Australia are the result of feral pigs being illegally translocated and released (Spencer and Hampton, 2005).

Feral pigs are relatively intolerant of heat and aridity. Their distribution is therefore largely limited by lack of cover or access to free water. The tropics of Queensland have the highest feral pig densities in Australia due to a particularly suitable combination of water availability, food resources and shelter (Figure 1). Climate matching indicates that there are extensive areas that feral pigs could occupy, where they are currently absent or in low densities (Braysher, 2000). These include large parts of central and eastern Tasmania, Eyre Peninsula, the south-east of South Australia, and south-western Western Australia.

Cowled et al. (2009) estimated the future distribution of a recently introduced, expanding feral pig population in the remote Kimberley region of north-western Australia. Computer modelling used weather data, remote sensing data and pig habitat preferences to identify suitable habitat. The study region was 89,125 km^2 in area. The modelling indicated that feral pigs could expand their distribution, by natural dispersal alone, to occupy 61,950 km^2 (approximately 70%)of suitable habitat within the study area.

2. Biology **(drawn from Choquenot et al. (1996))**

2.1. Appearance

Feral pigs in Australia are smaller, leaner and more muscular than domestic pigs, with well developed shoulders and necks and smaller, shorter hindquarters. They also have longer, larger snouts and tusks, smaller, mostly pricked ears (not pendant like those of many domestic pigs) and much narrower backs. Their hair is longer and coarser than that of domestic pigs. Some individuals develop a crest or mane of bristles extending from their neck down the middle of their back, hence the nickname ‘razorback’. These bristles often stand erect when the pig becomes enraged (Giles, 1980). The tails of feral pigs are usually straight with a bushy tip.

Male feral pigs (and in Eurasia, wild pigs) are renowned for their tusks, which project from the sides of the mouth. The lower tusks are triangular in cross section and curve upwards, outwards and backwards, forming an arc. They are generally 5–6 centimetres in length. The upper canines are shorter and oblong in cross section. They curve outwards and back, and remarkably, function as whetstones or grinders to the lower tusks (Pullar, 1953; McIlroy, 1990).

Regional populations of feral pigs vary in physical size, shape and coat colour, differences probably inherited from the breeds which initially escaped or were released. Black is the most common colour (Pullar, 1953; Pavlov, 1983). Other colours include rusty red and a high proportion of lighter or mixed colours, including white, light ginger, brown and white, brown with black spots and agouti patterned (brown or black hair with a lighter tip) (AMRC, 1978). Some feral piglets are marked with dark longitudinal stripes, which disappear as they grow older (Wilson et al., 1992). Such stripes are rarely seen in domestic piglets.

2.2. Size

Male feral pigs tend to be longer, taller and heavier than females (AMRC, 1978; Masters, 1979, 1981; Pavlov, 1980, 1983). While size is highly variable, adults generally range up to 115 kilograms for males and 75 kilograms for females. Feral pigs in the temperate forests of New Zealand may grow to over 200 kilograms and in Namadgi National Park, near Canberra, a 175 kilogram boar was caught (McIlroy, 1990). Average body length of adults is 105–155 centimetres for males and 100–130 centimetres for females.

2.3. Longevity and mortality

Feral pigs are relatively short-lived, and individuals older than 5 years are rarely recorded. Adult mortality can vary from 15 to 50% between year classes[†] (Giles, 1980).

Mortality in young feral pigs during their first year of life is generally high, particularly from the foetal stage to weaning, but it can vary from 10–15% when food supplies and weather are favourable, to 90% where conditions are poor, and even 100% during drought (Masters, 1979; Giles, 1980; Saunders, 1988).

The main causes of mortality in feral pig populations generally are loss of foetuses, accidental suffocation of piglets by their mothers, loss of contact between piglets and mothers, and starvation at all ages, including in old pigs when excessive tooth wear interferes with chewing.

Dingoes (*Canis lupus dingo*) and feral dogs (*Canis lupus familiaris*) prey on piglets and are probably responsible for the frequent high mortality of immature pigs and sometimes mature females, but there is conflicting opinion about whether dogs limit the size or distribution of feral pig populations (Pavlov, 1983, 1991; Woodall, 1983; Saunders, 1988; Corbett, 1995; Fleming et al., 2001).

2.4. Reproduction

In Australia, female feral pigs (sows) start breeding at 25–30 kilograms in weight and 7–12 months of age (Masters, 1979; Giles, 1980; Pavlov, 1980). Feral sows have a 21–day oestrus (menstrual) cycle and a gestation period of 112–114 days. There are generally 5 or 6 piglets in each litter, but up to 10 piglets can be born in good conditions. Piglets wean at two to three months of age. The time for a feral sow to return to oestrus (fertility) after parturition (birth) is also variable, being up to 94 days (Giles, 1980; Pavlov, 1983).

Feral pigs have relatively high protein requirements, similar to those of domestic pigs, particularly for successful lactation (milk production) and growth of young. If intake of crude protein falls below 15% of the diet, lactation can cease and dependent piglets may die (Giles, 1980). The dietary energy needs of feral pigs are also relatively high, particularly for sows in the last month of pregnancy, which require about twice the digestible energy of non-breeding sows, and lactating sows which require up to three times the non-breeding energy requirements (Giles, 1980).

Breeding is usually seasonal due to variable food quality and availability. In the high country of Kosciuszko National Park, for example, most births occur in summer and autumn, in response to the spring flush of growth (Saunders, 1988). Feral pigs living on the semi-arid floodplain of western New South Wales generally breed continuously, but most pregnancies tend to occur after flooding when more food is available (Giles, 1980). Breeding also occurs throughout the year in feral pigs in the monsoonal tropics of the Northern Territory, with a peak in births during the early dry season (Caley, 1993).

[†] A year class is all the individuals in an animal population that were born in a specific year and are of the same, specific age. Most animal populations are made up of multiple year classes (e.g. age 0+, age 1 year, age 2 years, age 3 years, etc.). Individual animals in the population progress through these year classes until they die.

Prolonged drought can see feral pig numbers decline significantly. Conversely, favourable conditions (i.e. high rainfall and/or flooding) can see feral pig numbers increase rapidly. Under favourable conditions, sows can produce two weaned litters every 12–15 months (Giles, 1980; Pavlov, 1983; Ridpath, 1991). This potentially high reproductive rate gives feral pig populations the capacity to recover quickly from natural setbacks and control programs and is a major factor to be considered in their management. Published maximum reproductive rate (r_{max}) estimates for feral pigs suggest that ~55–70% of a pig population needs to be removed throughout the year to keep the population size stable (Bengsen et al., 2014).

2.5. Habitat

The most critical factors affecting the distribution and habitat use of feral pigs in Australia are their poor heat tolerance and the accompanying need for access to daily water and dense shelter. This largely restricts their distribution to the vicinity of watercourses and associated floodplains in inland or seasonally dry areas of Australia. These factors are less critical in the more forest-covered parts of eastern Australia and south-west Western Australia, where populations are still spreading.

Within these limitations however, feral pigs are habitat generalists and occupy a wide range of habitats in Australia, including the subalpine grasslands and forests of Kosciuszko National Park, the semi-arid floodplains (often dominated by lignum (*Muehlenbeckia florulentum*)) in western New South Wales, the *Typha* and *Phragmites* reed beds of the Macquarie Marshes in central New South Wales, the rainforests in the Wet Tropics of northern Queensland, and the paperbark *(Melaleuca* species) swamps, open floodplains, monsoon forest patches, *Mimosa* thickets and dry woodlands in the Northern Territory (AMRC, 1978; Giles, 1980; Saunders, 1988; Hone, 1990b; Bowman and Donough, 1991; McIlroy, 1993; Dexter, 1995).

2.6. Diet

Feral pigs are opportunistic omnivores, with strong preferences for succulent green vegetation, a wide variety of animal material, fruit and grain (Giles, 1980). Other foods include underground starch-rich plant material, such as roots, bulbs and corms. Pigs have a single stomach, with a poor capacity to digest cellulose, so they cannot feed solely on roughage as ruminants do.

The items eaten by feral pigs in Australia vary from region to region, but include:

(a) Fruits and seeds:
Figs, palms, pandanus and other rainforest trees; cycads (*Macrozamia* species); bush peanuts (*Elaeocarpus* species); sweet briar (*Rubus rubiginosa*); wattles (*Acacia* species); geebungs (*Persoonia* species); *Coprosma* species; bananas, mangoes and a wide range of orchard fruit; grasses; and crops such as pumpkins, watermelons, potatoes, peanuts, taro, maize, wheat, oats, sorghum and other cereals.

(b) Foliage and stems:
Small palms, pandanus and other rainforest seedlings; young coconut and banana trees; sugarcane; succulents such as pigweed (*Portulaca oleracea*); semi-aquatic ferns (e.g. nardoo (*Marsilea drummondii*)); the Gondwanan relict wetland species reedia (*Reedia spathacea*); and a range of forbs[‡], grasses and legumes, including native medics (*Medicago* species), introduced clovers, lucerne and paspalum, native grasses (e.g. *Poa* species) and young wheat.

(c) Rhizomes, bulbs and tubers:
Lilies (e.g. stream lily, flax lily (*Helmholtzia* species) and vanilla lily (*Arthropodium milleflorum*)); grasses, sedges and rushes such as spike-rushes (*Eleocharis* species), *Cyperus rotundus*, *Setaria sphacelata*, common water-reed (*Phragmites* species), cumbungi or bullrush (*Typha* species), *Scirpus* species and sedges (*Juncus* species); bracken (*Pteridium esculentum*);

[‡] herbaceous flowering plants other than grasses and sedges

introduced dock (*Rumex* species) and thistles (Family Asteraceae); numerous orchid species; native geranium (*Geranium solanderi*); *Oxalis* species; yams and other tropical rootstocks (*Ipomoea*, *Dioscorea* and *Ampelocissus* species); and cycads (*Macrozamia* species).

(d) Fungi:
Underground and above-ground

(e) Animal material:
Earthworms, snails, arthropods (especially beetles), crustaceans, shellfish, frogs, fish, reptiles (including turtle eggs), eggs of ground-nesting birds, birds, mice, young rabbits, lambs and other small mammals and carrion.

(Sources of information: Pullar, 1950; Masters, 1979, 1981; Giles, 1980; Boreham, 1981; Alexiou, 1983; Hopkins and Graham, 1985; Statham and Middleton, 1987; Bowman and McDonough, 1991; Pavlov, 1991; Ridpath, 1991; Pavlov et al., 1992; Mitchell, 1993; also Jones et al., 2008; TSSC, 2008).

Both the availability and the nutrient levels of the various foods feral pigs consume changes seasonally. For example, in central and western New South Wales, feral pigs feed mainly on green herbaceous material when it becomes available after heavy rain or floods (Giles, 1980). During dry periods they eat roots, carrion and little else. In the Girilambone area in central New South Wales, they mainly eat forbs such as potato bush (*Solanum ellipticum*) and insects in autumn, native medics (*Medicago* species) (with their high protein content) in winter, and wheat in spring and summer. Roots, however, are the most consistent food item in all seasons (Pavlov, 1980). Studies in New South Wales have shown consumption of animal matter varies greatly between seasons but rarely exceeds 5–18% of the diet (Giles, 1980; Pavlov, 1980).

An international literature review reported that feral pigs prey on soil fauna including insect larvae, beetles, snails, centipedes and earthworms, reducing their abundances between 40 and 90%. This review also found animal matter can make up to 30% of feral pig diet (Barrios-Garcia and Ballari, 2012), though this is a higher figure than found in Australian studies.

3. Environmental impacts

3.1. Overview

This overview examines the environmental impacts of feral pigs. However, feral pigs also have significant economic impacts for primary producers (see 'Economic Impacts' section).

The environmental impacts of feral pigs in Australia take many forms. These include predation of animals and consumption of plants and soil organisms; habitat change and degradation due destruction of plants, reduced plant regeneration, soil erosion and changes in soil structure and the spreading of weeds. Feral pigs act as reservoirs for diseases and spread plant pathogens such as *Phytophthora cinnamomi* which causes "dieback". Feral pig impacts are particularly associated with wetlands and riparian ecosystems, which are preferred habitats. This also leads to impacts on water quality (water turbidity and dissolved nutrient levels).

The most significant environmental impact feral pigs have is related to the degradation of habitats and predation of native species. Habitat degradation by feral pigs is mostly due to their digging up of soils, grasslands and forest litter as they forage or 'root' for subterranean food items such as roots and fungi. Moist soils particularly attract digging activities. Pig disturbance can be locally extensive, such as in or around swamps and lagoons, and may be associated with sites modified by people, or close to roads, tracks and watercourses. Foraging can result in obvious large expanses of deeply turned over or rooted soil in highly profitable foraging patches. More commonly, damage is distributed discontinuously throughout a broad area,

often following a negative exponential frequency distribution, such that a few sites experience high levels of damage while many sites have little (Bengsen et al., 2014).

A combined review/field study of feral animal impacts on native vegetation, and techniques to measure their impacts, concluded that using indicator plant species was not a good measure of feral pig impacts. General pasture impacts (including both introduced and native plants) was a better measure, as pigs forage into the soil profile and dig for plant roots, particularly focusing on pasture plants (Lethbridge et al., 2013). The same study stated that vegetative damage caused by pig diggings was striking. The amount of bare ground in recent diggings was almost 100% and there was a 78% reduction in total plant biomass compared to nearby 'no-digging' areas. However, it noted that damaged/destroyed vegetation will 'recover' or 'reset' over time—but whether this recovery brings the digging sites back to the 'pre-dug' condition was unclear and required further long-term studies (Lethbridge et al., 2013).

The study of Lethbridge et al. (2013) also reported findings similar to numerous previous studies. The location of pig diggings were strongly influenced by the presence of microhabitat variables, especially water. Intense diggings occurred in these small, preferred microhabitats where there is food, cover and water, while larger areas of less favourable microhabitats tended to have low levels of diggings. The association of pig density with the extent of diggings was positive.

Feral pig activity often results in increases in exotic plant (weed) abundance, although whether this is through passing seeds in faeces, spreading seeds attached to fur, creating localised nutrient enrichment through urine and faeces, or simply by creating ground disturbance in which exotic plants can take root, is not certain. Evidence indicates feral pigs can spread many Weeds of National Significance in Australia including pond apple (*Annona glabra*) (McIlroy, 1993; Fensham, 1996; Grice, 1996; Lynes and Campbell, 2000; Setter et al., 2002), and field evidence from Queensland shows viable mesquite seedlings can sprout from pig faeces (Queensland DPI&F), 2008). However, an international literature review found feral pigs damage most or all seeds that they consume, so the primary means of exotic plant dispersal may be through fur attachment (Barrios-Garcia and Ballari, 2012).

There is increasing evidence that feral pigs spread the plant pathogen *Phytophthora cinnamomi*. Three of four feral pigs examined in Hawaii were found to be carrying the organism in soil on their hooves (Kliejunas and Ko, 1976). Similarly, a New Zealand study detected 19 plant pathogens on the trotters and snouts of 457 feral pigs in New Zealand, including *P. cinnamomi* (Krull et al., 2013b). Feeding trials with *Phytophthora*-inoculated plant materials have demonstrated that *P. cinnamomi* spores can survive passage through the guts of pigs and that viable spores are excreted up to seven days post-ingestion (Li et al., 2013).

Fauna preyed upon by feral pigs include earthworms, amphipods, centipedes, beetles and other arthropods, crustaceans, snails, frogs, lizards, snakes, the eggs of the freshwater crocodile (*Crocodylus johnstoni*), freshwater turtles and their eggs, marine turtle eggs and hatchlings, and small ground-nesting birds and their eggs (Tisdell, 1984; McIlroy, 1990; Mitchell, 1993; Roberts et. al., 1996).

3.2. Impacts by region

The following sections describe some of the known impacts from feral pigs in particular regions and/or ecosystems:

3.2.1. Tropical savannahs

In the tropical savannah areas, feral pigs have the greatest impacts on biodiversity in ephemeral lagoons and wetlands. Most of the reported damage comprises rooting and consumption of riparian and aquatic vegetation and predation on freshwater aquatic species. In coastal areas feral pigs are serious predators of eggs and hatchlings from marine turtle nests.

3.2.1.1. Predation

Feral pigs are a significant predator of freshwater aquatic species in northern Australia. Frogs, freshwater crayfish and freshwater turtles are all preyed upon (Mitchell, 2010). For example, over 150 frogs were found in a single pig stomach in the Cape York region (Mitchell, 2010).

Feral pigs are serious predators of freshwater northern longneck turtles (*Chelodina rugosa*) in northern Australia. These freshwater turtle species burrow into sediments as post-wet-season lagoons/wetlands dry out, and then aestivate in sediments until the next wet season. 38 northern longneck turtles were radio-tracked through the simultaneous processes of the drying out of the lagoon and initiation of aestivation. The radio-tracking revealed only 10 turtles (26%) were alive at the completion of the drying-out/aestivation process (Fordham et al., 2006). Feral pigs were the main predator, causing 27 of 28 recorded deaths (96%). Photos of the aestivation sites over time revealed that feral pigs actively seek out and prey on aestivating turtles. Aestivation depth of the turtles never exceeded pig rooting depth. The study's authors concluded that unless pig predation is severely reduced, Aboriginal people may have no choice but to abandon their ancient and hitherto-sustainable low-level harvest of these turtles, an action that will have damaging cultural consequences (Fordham et al., 2006).

A second study modelled the impact of feral pig predation on freshwater northern longneck turtles using field-derived data from Arnhem Land (Northern Territory). It found that levels of turtle mortality per lagoon/wetland caused by feral pigs (≥40%) exceeded levels that turtle populations can sustain over a 50 year timeframe. It concluded that if feral pig predation is left unmanaged, turtle populations in northern tropical Australia are under severe threat, and that extirpation of many turtle populations in the near future is all but assured. Conversely, the study found that in the absence of pig predation, compensatory increases in hatchling survival were sufficient to allow a traditional annual Aboriginal harvest of up to 20% of sub-adult and adult turtles without causing extirpation or substantial population suppression (Fordham et al., 2008).

A separate study recorded serious degradation and destruction of lagoon/wetland turtle habitats by feral pigs in Lakefield National Park, but also demonstrated that fencing of lagoons/wetlands utilised by turtles can prevent pig impacts (Doupé et al., 2009).

Predation of marine turtle nests on beaches by feral pigs is common. The National Recovery Plan for Marine Turtles in Australia (EA, 2003) recognised that feral pigs are responsible for high levels of nest predation on nesting beaches used by marine turtles. The marine turtle populations affected by feral pig predation of nests or hatchlings have been identified as:

- loggerhead turtles (*Caretta caretta*) from the eastern and western Australian populations
- green turtles (*Chelonia mydas*) from the southern Great Barrier Reef, Gulf of Carpentaria and North West Shelf populations
- flatback turtles (*Natator depressus*) from Arnhem Land, Gulf of Carpentaria, Queensland and North West Shelf populations
- olive ridley turtles (*Lepidochelys olivacea*) from the Northern Territory population
- hawksbill turtles (*Eretmochelys imbricata*) from the north-eastern Australian populations (EA, 2003).

Figure 2. Photo showing an autopsy of a feral pig that had been preying on marine turtle hatchlings in north Queensland. The photo shows at least 32 hatchlings from one pig. (Photo: Australian Quarantine and Inspection Service (AQIS), Cairns.)

A second study in region tested a decision framework that prioritised pig management actions to reduce pig predation on flatback turtles (*Natator depressus*), and made similar findings (Fuentes et al., 2014). The study noted that the most important nesting sites for this population are in the north-east of the Gulf of Carpentaria (e.g. Crab Island) and western Torres Strait (Fuentes et al., 2014). This study found that predation of nests is one of the greatest threats to mainland flatback populations, with more than 80% of nests affected in some areas, with most of the egg predation being from feral pigs. This study also found that mixed strategies were more effective at reducing pig predation than aerial-culling-only strategies due to the fact that mature pigs that live on the beachfronts are usually the major egg predators. These pigs are not fully controlled by aerial-only strategies, so it is also important to identify and kill these pigs on the ground as well as to protect nests (Fuentes et al., 2014).

3.2.1.2. Habitat degradation

Mitchell (2010) carried out in-depth investigations on the impact of feral pigs on ephemeral lagoons and wetlands in tropical savannah/floodplain regions in Lakefield National Park (Cape York, Queensland), based primarily on comparisons of fenced and unfenced lagoons and wetlands. Feral pigs had a marked negative impact on the ecological condition of unfenced lagoons and wetlands as they shrank over the course of the dry season. Feral pig foraging activities caused major destruction of aquatic vegetation. Feral pigs also affected water quality, causing significant increases in turbidity and nutrient levels (from their bodily wastes), and reducing dissolved oxygen levels and pH levels to biologically stressful levels. Mitchell (2010) found that if pig diggings covered more than 25% of unfenced lagoon perimeters there was a rapid reduction of plant/water plant richness, which declined to zero when pig diggings became extensive. Mitchell (2010) also suggested that pig disturbance may affect water body permanence where the lagoons are very shallow with broad wetland margins.

Doupé et al. (2009, 2010) recorded serious degradation and destruction of lagoon/wetland turtle habitats by feral pigs at the same sites used by Mitchell (2010), but demonstrated that fencing of lagoons/wetlands utilised by turtles can prevent pig impacts.

3.2.1.3. Competition

Feral pigs are likely to compete with brolgas (*Grus rubicundus*) and magpie geese (*Anseranas semipalmata*) for tubers and bulbs in northern Australia (Tisdell, 1984).

3.2.2. Wet Tropics

3.2.2.1. Predation

Feral pigs also undermine shrubs and trees by their digging, causing them to topple (Mitchell, 1993), but it is not clear if other factors, such as cyclone damage, may also have had a contributory effect (McIlroy, 1993). Feral pigs do not cause significant damage to, or eat, tree-ferns in the Wet Tropics of Queensland, in contrast to their behaviour in Hawaii and New Zealand (McIlroy, 1993). However, in the Whitsunday Ranges, feral pigs feed heavily on the seeds and juvenile plants of the Alexandra palm (*Archontophoenix alexandrea*) and dislodge further juvenile palm plants with their diggings, to the point where no small palms were surviving in study areas prior to pig control (Nolan and Bennison, 2014).

Studies have reported conflicting results on pig predation of earthworms in the Wet Tropics. One study found that feral pigs harvested over 95% of the available worms at paired sites in ephemeral swamps near Cape Tribulation (Pav Ecol, 1992), while a second study found identical numbers of earthworms in feral pig diggings and surrounding areas in the same general region (Mitchell, 1993).

Feral pigs, through either direct predation or habitat disturbance, may have contributed to the declines in some populations of endemic tropical rainforest frogs and may have contributed to the extinction of the gastric brooding frog (*Rheobatracus silus*) (Richards et al.,1993).

Feral pigs are reported to destroy nests and eat eggs and young of cassowaries (*Casuarius casuarius johnsonii*), scrubfowl (*Megapodius reinwardt*) and brush-turkeys (*Alectura lathama*), (Hopkins and Graham, 1985; Crome and Moore, 1990; Mitchell, 1993). However, an Australian literature review of feral pig impacts reported that monitoring of artificial nests provided no evidence of predation by pigs, and that researchers concluded native rodents were the dominant predators (Bengsen et al., 2014).

In northern Cape York Peninsula (Queensland), feral pig diggings and disturbance are implicated in disappearance of the Jardine River Painted Turtle (*Emydura subglobosa*), which was not found during an extensive 2008 survey of the Jardine River (Schaffer et al., 2009). In fact, this survey failed to catch any freshwater turtles at all, despite four freshwater turtle species being known from northern Cape York Peninsula.

In discussing this result, the researchers comment that:

> "... the usual threats ... like river regulation and industrial or agricultural pollution can be ruled out. What we did notice, however, were the ubiquitous diggings by foraging feral pigs ... In the early 1980s, one of us hunted wild pigs in the Jardine River area and saw no sign of pigs or their foraging activities near the river ... In 2008 pig disruption of the river banks was extensive, suggesting that their numbers and impacts are increasing. It is hard to conceive this level of disturbance not having some effect on turtle populations, for example, through ... predation, disruption of nesting activities, or impeding movement between the river and adjacent habitats." (Schaffer et al., 2009)

(In 2014 a small population of painted turtles, considered threatened by feral pigs, was rediscovered (ABC Online, 2014)).

3.2.2.2. Habitat degradation

Feral pig digging may cause significant erosion of creek banks in the rainforests of Queensland, leading to the silting of downstream swamps (McIlroy, 1993, 2001). This may be minor, though, compared to the concentration of suspended sediment in streams in the area from vehicles crossing them, and from the widespread overland flow of water and saturated soil profiles associated with torrential rainfall, particularly from cyclones during the wet season (Gilmour, 1971; Gillman et al., 1985).

A study in the Wet Tropics World Heritage Area (Queensland) found feral pigs had dug up 4.3% of the ground surface at 31 randomly selected sites. Approximately 70% of pig diggings were within ten metres of a road, track, surface water or a drainage line, particularly along watercourses (36%) and drains (8%). Only 1% of the ground surface more than ten metres away from roads and watercourses had been dug up (Mitchell and Mayer, 1997; Mitchell, 2001). This study did not find any significant impact on earthworm populations, root biomass, soil moisture and litter biomass by these pig diggings. However, revegetation was slow in areas that had been dug over by feral pigs and the dominant grassy vegetation and some small native herbs were greatly reduced in abundance (Mitchell, 2001).

Similarly, a study comparing plots where feral pigs had been excluded long term (12 years) with unprotected plots found feral pigs had caused significant declines in seedling density, soil macroinvertebrate density and leaf litter cover, but caused no significant change in a number of other variables (Taylor et al., 2011). An Australian literature review of feral pigs impacts compared the results this study and a subsequent study. The subsequent study used plots protected from feral pigs for two years, and the same long-term plots from the first study and found no statistically significant differences between seedling densities in protected and unprotected plots (Elledge et al., 2011, in Bengsen et al., 2014). Neither study found detectable differences in soil characteristics such as pH, conductivity or nutrient statuses after 12 or 14 years of pig exclusion. Long term changes in plant community composition could not be ruled out however (Bengsen et al., 2014).

An Australian literature review concluded populations of widespread generalist plant species are unlikely to be affected by feral pigs because diggings tend to be concentrated in profitable foraging areas, allowing seedlings in less favoured areas to escape. However, areas favoured by pigs for digging may also be the preferred habitats of specialist plant species. North Queensland rainforests, for example, support many rare and endemic plant species, some of which are largely restricted to the vicinity of drainage features (e.g. creek lines, swamps) where feral pigs concentrate their digging activities (Bengsen et al., 2014).

3.2.2.3. Competition

Feral pigs may compete with specialist feeders such as the mainly fruit eating cassowaries, by feeding on a temporarily abundant food source such as fallen rainforest fruit, until the supply is almost depleted, before switching to others, such as sugarcane (Tisdell, 1984; Buosi and Burnett, 2006). An Australian literature review of feral pig impacts however found no reliable information to evaluate these suggested impacts (Bengsen et al., 2014).

3.2.3. Temperate forests and grasslands

3.2.3.1. Predation

In temperate forests of south-western Western Australia, feral pigs have been identified as a major problem to declared rare flora taxa, particularly geophytes such as orchids (Hearn et al., 2006). Pig diggings have been identified as a key threat to the majestic spider orchid (*Caladenia winfieldii*) as they destroy the underground storage tubers of the orchid and affect the growth of symbiotic fungi essential for providing starches for plant and seed germination (Hoffman and Brown, 1992).

3.2.3.2. Habitat degradation

Feral pigs can degraded temperate forest by spreading the plant pathogen *Phytophthora cinnamomi* (also known as “dieback”). There is increasing evidence that feral pigs spread this plant pathogen (Kliejunas and Ko, 1976; Krull et al., 2013b, Li et al., 2013).

An international review found that nest building by pregnant females, creating wallows (mud hollows in which pigs roll) and tree rubbing may also contribute significantly to vegetation damage in forest areas (Barrios-Garcia and Ballari, 2012). In New Zealand temperate rainforests, Krull et al. (2013a) found significantly more nitrate in pig-disturbed plots. Seedling density was not significantly reduced, but seedling/sapling species richness [i.e. number of different species] was reduced and species composition was altered (Krull et al., 2013a).

An international review found digging by feral pigs can adversely affect soil nutrient cycling and erosion, but the extent of this impact is not quantified. The enrichment of areas with nutrients from feral pig waste may remove the competitive advantage that endemic plants adapted to lower nutrient levels have over introduced plants (Barrios-Garcia and Ballari, 2012).

There is a strong correlation between digging damage and soil moisture (Hone, 1988, 1995, 2002), soil friability and the presence of large numbers of earthworms, other invertebrates and bulb-producing plants. A few feral pigs can dig up a significant area. The ground disturbance within natural areas caused by feral pigs, especially national parks and reserves, is often obvious and a major source of concern to park users (Hone, 2002). Managing complaints about soil disturbance may be the main aim of some feral pig management programs. In Namadgi National Park, A.C.T., a large reduction in the feral pig population was required to get a significant reduction in ground digging (Hone, 2002).

In Strzelecki National Park on Flinders Island, feral pigs dig up extensive parts of the moist rich gullies, leading to erosion, loss of regenerating forest plants and their replacement by thick, impenetrable stands of bracken fern (*Pteridium esculentum*) (Statham and Middleton, 1987).

Feral pigs have the potential to indirectly affect quokka populations (*Setonix brachyurus*), listed as vulnerable under the EPBC Act, through destruction of habitat. This removes food resources from the habitat and creates pathways which facilitate access for other feral animals, such as foxes (May and Norton, 1996; Meek and Saunders, 2000). Anecdotal reports and research by Bain et al. (in prep.) suggests that sites within south-western Western Australia, where the long-term ‘Western Shield’ cat and fox baiting program takes place, and which previously supported quokka populations, become unsuitable for quokkas after they have been disturbed by pigs (WA DEC, 2013).

3.2.4. Temperate wetlands/marshes

3.2.4.1. Predation

The rare Gondwanan-relict sedge species reedia (*Reedia spathacea*), listed as endangered under the EPBC Act, and found in wetlands of south-western Western Australia, is targeted by feral pigs and easily killed by them. This is due to essential tap roots issuing from the top of the plant, where they are easily severed by feeding pigs (TSSC, 2008). The threatened white-bellied frog (*Geocrinia alba*) (EPBC: endangered), the orange-bellied frog (*Geocrinia vitellina*) (EPBC: vulnerable) and the sunset frog (*Spicospina flammocaerulea*) (EPBC: endangered) found in these habitats are also negatively affected by the activities of feral pigs (WA DPaW, 2014; Burbidge and Roberts, 2002).

3.2.4.2. Habitat Degradation

The unique wetlands of south-western Western Australia, including a number of peat swamps habitats, and areas with moist organic soils, are seriously degraded by rooting activities of feral pigs and nutrient enrichment and pollution from their bodily wastes.

3.2.5. Alpine/sub-alpine areas

At Smokers Gap, in the Australian Capital Territory, drainage lines, depressions, and grassy flats were the areas of sub-alpine vegetation most susceptible to damage by feral pig digging (Alexiou, 1983). Feral pig diggings along drainage line have had particularly destructive effects on orchid species after the 2003 bushfires burnt this area (Jones et al., 2008).

3.3 Feral pig densities and landscape and food resource use

The relationship between pig density and environmental damage is still being researched, but clearly varies between locations and ecosystems. A study in the southern highlands of New South Wales demonstrated a positive relationship between feral pig density and the extent of rooting/digging (Hone, 2002). A study in tropical savannahs in Cape York (Queensland) also found the level of impact caused by pig diggings is positively associated with the level of pig abundance, i.e. more pigs, more diggings. The study also found that when pig abundance is high, a minimal level of population control will substantially reduce impacts, while when pig abundance is low, a substantial level of pig control is required for a minimal decrease in impact levels. The study found that the point where control measures had maximum effectiveness for effort was when pig visitation frequency reached 50% in plots being monitored for signs of pig presence (Mitchell, 2010). In contrast, a study in western Cape York found that most pig predation on turtle nests were the result of small numbers of individual (territorial) pigs predating within their specific areas of beach (Whytlaw et al., 2013).

Seasonal use of landscapes and resources by feral pigs in Australia is not fully understood. It is an area of active research and new findings are being made. For instance, recent studies found feral pigs were using the Whitsunday Great Walk track as a thoroughfare to feed on Alexandra palms (*Archontophoenix alexandrea*) in the Whitsunday Ranges, and also identified the pigs' use of four seasonal food groups (Nolan and Bennison, 2014). These were: palm seeds (November through to Jan/Feb); earthworms (Feb/March, sometimes into April); palm hearts (heads) (April/May through to July); and generalist feeding (mainly invertebrates) (August to November). Transition between food groups was approximate, and in some cases dependent on the end of the wet season and soil saturation levels (e.g. earthworms). This enabled the researchers to confirm, through trials and the use of remote cameras, that the best time to bait pigs in the area was September/October with early to mid-October being the optimum. At this time of year that pigs were observed fighting over baits and would readily consume baits soon after they were first encountered. A final finding was that pigs were found to be feeding heavily on palm seeds and juveniles, to the point where no small palms were surviving (Nolan and Bennison, 2014).

Another study found that feral pigs in the Wet Tropics have small home ranges of 3–10 km^2 and very little seasonal movement due to abundant food, water and shelter. This study found protein content in the diet was important and guided landscape use, with earthworms targeted during the wet season (commencing January/February) and fallen fruit in the dry season, with fallen fruit peaking in September. Some pigs used rainforest/cane field boundaries and moved into the cane fields for foraging and shelter in the dry season (Fletcher et al., 2014).

One impediment to understanding landscape use by pigs has been the difficulty of spotting pigs when they are in forest habitats. However recent aerial trials using fixed wing aircraft and downward-facing thermal sensors successfully detected pigs at several altitudes under forest canopy providing up to 98% ground cover (Adams and Rampant, 2014).

4. Disease

Feral pigs have been identified as actual or potential reservoirs and vectors for a number of disease and parasites including foot-and-mouth disease, leptospirosis, brucellosis, melioidosis, tuberculosis and sparganosis (Pullar, 1950; Keast et al., 1963; Geering et al., 1995; Wilson and Choquenot, 1996; ARMCAZ, 2000; Black, 2004; Sharp and Saunders, 2012).

An Australia literature review of feral pig impacts reported that the two most common diseases isolated from feral pigs in Australia are the bacteria *Leptospira* spp. and *Brucella* spp. These can cause brucellosis and leptospirosis, resulting in birth defects, abortion and infertility in livestock and humans. Nearly all human cases of brucellosis reported between 1996 and 2009 in Townsville were in feral pig hunters, and feral pig hunting is the greatest risk factor for brucellosis infection in Australia. Feral pig hunters may also acquire sparganosis by consuming *Spirometra* helminths or *Trichinella* nematodes in undercooked pig meat. *Spirometra* can be highly prevalent in feral pigs in north Queensland, where consumption of pig meat is common in remote communities (Bengsen et al., 2014).

The literature review also found pathogenic organisms such as *Escherichia coli*, *Giardia*, *Cryptosporidium* and *Balantidium coli* can cause serious illness or death in people who consume water or agricultural produce contaminated by feral pigs (Bengsen et al., 2014). Similarly, a study of a remote, isolated pig population on the Fitzroy River floodplain in the Kimberleys (Western Australia) found the population consistently carried *Salmonella* bacteria. The *Salmonella* bacteria was transmitted from older to younger pigs, possibly via landscape features such as water features, which may have implications for infection of co-grazing livestock within that environment (Ward et al., 2013).

Feral pigs are also susceptible to many important exotic pathogens, such as the foot and mouth disease (FMD) virus. The total cost to the national economy of an FMD outbreak in Australia has been estimated at between 3 and 13 billion AUD, depending on the outbreak's duration. Wild pigs may be important contributors to the persistence and transmission of any FMD outbreak in Australia because they are highly susceptible to the virus, they are highly abundant in northern Australia, they are often in close contact with livestock, and they are highly efficient amplifiers and transmitters of the virus. The wide range of situations in which wild pigs occur also makes it difficult to predict the spread and persistence of an FMD outbreak (Bengsen et al., 2014).

The potential for feral pigs to transmit diseases of any kind to livestock is high in areas such as semi-arid extensive pastoral systems, where pigs may occur at locally high densities near water, and stock can become infected from contact with contaminated substrates such as water, soil and, in some cases, air (Bengsen et al., 2014).

It is not known what effect the variety of pathogens feral pigs harbour or vector have on native wildlife.

5. Community perception

Feral pigs are variously regarded an agricultural pest, a disease carrier, an environmentally-damaging pest, an export commodity and a recreational resource (Choquenot et al., 1996). The status of feral pigs in any of these categories can vary with location, time and observer perception. This can lead to conflict in developing and implementing feral pig control programs that are aimed at addressing environmental problems. Similarly, a poor understanding of feral pig problems and issues can lead to unrealistic perceptions of feral pig problems and unrealistic expectations of control programs.

Recognition of the problem of feral pigs in the general community is still poor, despite information being readily available. This may be because feral pigs generally do not impact on towns and cities. Conversely, agricultural and environmental impacts from feral pigs are well recognised within rural communities and natural resource management community groups (DSEWPAC, 2011).

Governments at all levels have a major role in developing community understanding and awareness through appropriately packaged and targeted information. Non-government groups such as landholder community groups, industry groups and associations, animal welfare

societies, hunting groups and conservation societies can also play an important role in conducting or supporting control programs, and are key groups to target with educational material. Special attention should be given to providing information about the potential risks and problems due to feral pigs to key stakeholders, such as recreational hunters and bushwalkers. Land managers where jurisdictions require they undertake feral pig control will also require specific information.

5.1. Indigenous communities

Feral pigs are found on some lands owned or managed by Aboriginal and Torres Strait Islander people. As is the case for other Australians, there is no one attitude held by all Indigenous groups (Roberts et al., 2001). Attitudes vary considerably across the country and are changing with time. Some of the issues and concerns are:

- hunting and commercial harvest of feral pigs is often used by elders to encourage young people into the field to teach them traditional knowledge and as a way of helping to maintain the kinship system, and provide employment and additional cash flow to Indigenous communities
- feral pigs are an important supplement to the diet of Indigenous people in some remote areas
- for some groups such as Torres Strait Islanders, feral pigs are a traditional feast animal at ceremonies
- "too many pigs" are seen as a threat, especially from the perspective of disease outbreak, for groups that run pastoral operations
- the damage that feral pigs may cause to traditional food sources (roots and tubers), to totemic species and to the cultural landscape (Roberts et al., 2001).

Managing feral pigs where they are having environmental impacts but are also a resource for an Indigenous community is a particular challenge. Fordham et al. (2006) describe this challenge in relation to freshwater northern longneck turtles, which are seriously threatened by feral pigs:

> "Feral pigs in Arnhem Land present a management paradox since feral animals often constitute a culturally and economically important resource for Indigenous people ... Communities at a regional level must collectively choose between an annually available food source in the form of pig meat and conserving the traditional harvest of [northern longneck turtles], a food source that is at best seasonally abundant. Effective management can only be achieved if all stakeholders choose to view pigs as a pest ..."

Koichi et al. (2012) reviewed the literature on the many and varied Indigenous opinions on feral pigs, as well as providing opinions of Aboriginal Rangers from the Wet Tropics. They report that Aboriginal people who rely on bush tucker, which is subject to pig damage, were usually in favour of pig control. Conversely, in north-western Arnhem Land, pigs were valued as a resource to be used for game meat and safari activities because few commercial opportunities existed in such remote areas. Feral animals have become an important component for subsistence in far north Queensland, where many native prey have become scarce or extinct and pigs have become a major source of protein. In this area, the economic necessities of relying on fresh pig meat, instead of expensive store-bought food, and the social and cultural value of pig hunting, were stressed. Aboriginal Rangers recognised these 'positive' aspects of feral pigs but were very cognisant of the severe environmental damage feral pigs cause, including to traditional food sources, and the need for effective pig control.

5.2. Agricultural producers

Feral pigs are viewed variously by the agricultural community. Some producers see feral pigs as a potential resource, especially when the game meat price is high and/or the price of

agricultural commodities is low. However, the majority of producers view feral pigs negatively because of the damage they cause to livestock and crop enterprises, and also because of their potential role in outbreaks of exotic diseases.

Achieving broad scale control of feral pigs in an agricultural landscape can be challenging even where the feral pigs are viewed negatively. Gaining the support of sufficient landholders to ensure there are no gaps in the control program is essential. The use of remote sensing cameras is a useful tool to demonstrate to land managers that feral pigs are present in the area and using their properties. To be effective multiple control methods are required and the timing of application of the methods also needs to fit in with the different crops, lambing or other activities being conducted (Marshall et al., 2014).

5.3. Recreational hunters

Significant numbers of recreational hunters pursue feral pigs, many of whom view feral pigs as a game animal and a positive recreational resource. Feral pigs are most commonly taken by hunting on foot, with or without dogs, or from vehicles. Some recreational hunters believe that they have a useful role to play in broadscale feral pig control, though the evidence does not support this. Occasionally however recreational hunters can play a role in targeted management programs. Burt et al. (2011) report some successful use of volunteer hunters and GPS-collared dogs when eradicating feral pigs in fenced conservation areas in Hawaii, but also reported waning hunter interest and participation as catch rates dropped off. These conservation areas have subsequently had problems with people, presumably hunters, damaging fences and reintroducing pigs.

Both public and private landholders have deep concerns about some aspects surrounding the hunting of feral pigs. These include problems with trespassing and property damage by a minority of hunters, stock harassment, dogs left behind after hunting that later become a problem (i.e. establish as wild dogs), and deliberate introductions of pigs. The deliberate movement and introduction of feral pigs by hunters into areas of Australia which formerly did not have them is a severe problem. For example, feral pigs are steadily establishing in south-western Western Australia due to ongoing illegal releases, and recreational pigs hunters have interfered with governmental control measures (Spencer and Hampton, 2005; WA Parks and Wildlife, unpubl. data, 2014).

5.4. Animal welfare groups

Animal welfare groups aim to protect animals from cruelty and improper exploitation, and encourage considerate treatment of animals regardless of their status in human society. While there is a range of views held by such groups, in general they oppose control practices that cause animals unnecessary pain or suffering, and desire cogent justifications for control programs before they commence. Such groups demand that only best-practice, most-humane control methods are used. Information about control methods are provided in the following chapter.

6. Control methods

There are a range of control methods and strategies for managing the damage caused by feral pigs. When strategically applied using well planned and appropriately resourced programs, they have been very effective in reducing the damage feral pigs cause. The most effective methods for large-scale management/control are poisoning and aerial shooting. However, these methods are less effective for managing feral pig damage in areas such as dense forest where access is difficult and methods such as aerial shooting are not feasible. There may be further restrictions on some methods, for example where non-target animals are at risk from the method or in areas close to human habitation (e.g. restrictions on the use of 1080 poison). A discussion of issues associated with some methods follows.

An over-arching Model Code of Practice for Feral Pig Control is available at: www.feral.org.au/wp-content/uploads/2012/09/pigCOP2012.pdf. Detailed guidance on the use of the various control methods for feral pigs, in the form of Standard Operating Procedures, is available at www.feral.org.au/tag/pig-sop/. Table 1 (end of this chapter) provides a summary of approved control methods by state and territory.

6.1. Trapping

Trapping is an effective method, however, the limited number of individuals it removes from feral pig populations means it rarely has meaningful impacts on pig abundance. Where trapping is utilised, it needs to be expertly applied, as feral pigs quickly become trap-shy if they suffer a near miss. There are some new advances in trap application. New South Wales National Parks and Wildlife Service has used auto-feed and satellite signal traps in remote areas so that animals can be removed when trapped. Past studies have investigated increasing the effectiveness of traps using more effective attractants and more effective trap design (Dorrington et al., 2001).

Prior to trapping, free feeding of bait is offered at sites where feral pigs are active. After selecting a suitable site, a trap is then erected and free feeding is continued for a number of days before the trap is set. After feral pigs have been caught they are shot whilst still inside the trap. Good trapping techniques may enable whole groups of feral pigs to be caught at one time with minimal impact on non-target animals.

The revised '*Standard Operating Procedure: PIG001: Trapping of feral pigs*' (Sharp, 2012a) offers detailed advice. In particular:

- "Traps should be set up at sites where vegetation can provide shade and shelter. Pigs have poor thermoregulation and can suffer greatly when exposed to extremes of heat and cold."
- "To minimise the possibility of dehydration and heat or cold stress, all traps must be inspected daily. Shade cloth or hessian can be used for protection during extremes of weather." (Sharp, 2012a)

6.2. Aerial shooting

Aerial shooting of feral pigs from a helicopter is used in extensive or otherwise inaccessible areas where the density of feral pigs is high (Sharp, 2012b). The effectiveness of this method is influenced by factors such as type of terrain, the amount of vegetation cover and flying conditions (Choquenot et al., 1996), but it is an effective and relatively cost-efficient method of quickly reducing feral pig populations. Aerial shooting can be a humane method of destroying feral pigs when it is carried out by experienced and skilled shooters and pilots.

The revised '*Standard Operating Procedure: PIG002: Aerial shooting of feral pigs*' (Sharp, 2012b) offers detailed advice.

6.3. Ground shooting

Although intensive ground shooting operations may reduce local populations of feral pigs, it is rarely effective for damage control and is not suitable as a long-term control method (Sharp, 2012c). Ground shooting, especially where dogs are used, can actually be counter-productive to other methods in that it can disperse feral pigs or make them more wary (Choquenot et al., 1996).

The revised '*Standard Operating Procedure: PIG003: Ground shooting of feral pigs*' (Sharp, 2012c) offers detailed advice.

6.4. Use of Judas pigs

Radio-collared 'Judas' pigs are used to locate groups of feral pigs that are difficult to find using other methods. This method involves attaching a radio-collar to a feral pig and releasing it with the expectation that it will join up with other feral pigs. Feral pigs are gregarious, although not to the point of forming large herds as goats do. The nuclear social unit is based around one to several females and their offspring. Other individuals may loosely associate with these groups particularly older adult males when females are in oestrus. Once their position is established, the feral pigs accompanying the Judas pig are either trapped or destroyed by shooting (refer to *PIG001 Trapping of feral pigs*, *PIG002 Aerial shooting of feral pigs* and *PIG003 Ground shooting of feral pigs* for further details on these methods of control). The Judas pig is usually allowed to escape so that it will search out other groups of feral pigs. Once eradication is achieved the Judas pig is located, then shot and the radio-collar retrieved (Sharp, 2012d).

The revised '*Standard Operating Procedure: PIG004: Ground shooting of feral pigs*' (Sharp, 2012d) offers detailed advice.

6.5. Poisons

Poisoning with poison baits is a widely-used feral pig control method. Poisoning is also generally the most effective and lowest-cost control method.

Generally, the only toxin now used for feral pig control is sodium fluoroacetate (1080). The toxin 1080 has several advantages in that it is odourless and tasteless (increasing bait acceptability), kills most pigs reasonably rapidly (3–8 hours, average 4 hours) and biodegrades fairly readily. Studies in the Fitzroy River region of north-western Australia observed signs of very sudden collapse and death without kicking in feral pigs poisoned with fermented wheat containing 1080, suggesting the technique is relatively humane (Twigg et al., 2005, 2006).

Conversely, the toxins warfarin and yellow phosphorus (CSSP) are considered inhumane and strongly discouraged, due to the severe physiological distress these toxins cause poisoned pigs, and the tendency for these toxins to take several days to kill. The '*Model Code of Practice for the humane control of feral pigs*' (Sharp and Saunders, 2012) classifies warfarin and yellow phosphorus as inhumane and states they must not be used.

The revised '*Standard Operating Procedure: PIG005: Poisoning of feral pigs with sodium fluoroacetate (1080)*' (Sharp, 2012e) offers detailed advice on controlling pigs through 1080 poison baits. In particular, it is recommended to use a pre-feeding program with non-poisoned baits to allow an assessment of what animals are eating the baits before poison is used. A pre-feeding program also ensures the maximum number of pigs take poisoned baits when the poisoned baits are put out (Sharp, 2012e).

The development of pig-specific 1080 baits assists in reducing non-target species poisoning. The product PIGOUT® for instance, is a cylindrical bait pellet that is large in size (to prevent consumption by native animals smaller than pigs), has an internal poison core (to prevent small native fauna making contact with the 1080), a flavour/aroma formulation attractive to pigs, and a green colour to reduce their attractiveness to native birds. While dying baits green discourages birds, nevertheless, birds and monitors do still consume (small) 1080 baits, introducing the risk of poisoning of these non-target species (Millar et al., 2014). The use of bait feeding dispensers designed to discourage or exclude animals other than feral pigs reduces non-target species poisoning. An example is the HogHopper™, a feeder box with heavy vertically-sliding doors, which allows feral pigs to gain access to the bait but which prevents non-target animals from accessing the bait. Similarly, in the Wet Tropics, the use of 1080-infused corn bait under light covers (that pigs can push aside) has effectively targeted feral pigs and reduced non-target species poisoning (Bengsen et al., 2011).

It is worth nothing that bait selectivity issues have been documented in feral pig populations in some parts of Australia. In western Cape York, feral pigs, particular large boars, have been

observed avoiding PIGOUT® style baits. In this area, oatmeal mixed with 1080 is proving more effective (J. Perry, pers. comm., 2014). Similarly, two studies on the effectiveness of 1080 baiting during dry seasons in the Fitzroy River region of north-western Australia found that fermented wheat and malted barley were the preferred baits. Lupins and commercial pig bait pellets were consumed in lesser amounts, indicating they are less acceptable/not acceptable to some pigs (Twigg et al., 2005, 2006).

In these studies, fermented wheat was prepared by soaking in equal parts of water for at least 24 hours. The inclusion of a small amount of blood and bone proved to be an attractant and became a standard additive. Fish oil was also tested but found not to be an attractant. At least several days pre-feeding with non-poisoned grain was found to be essential. Once poisoned grain was put out, bait take normally ceased with 1–3 days. Almost no native fauna ate the bait, except for several instances where wallaby/kangaroo species ate small amounts of bait. No dead native fauna were found during thorough searches for pig carcasses. These studies recorded effectiveness rates of 81–91% (i.e. estimated percentage of resident feral pigs in study sites killed) (Twigg et al., 2005, 2006).

Another study tested the palatability of five grain-based baits, and the effectiveness of preferred baits when treated with 1080, on feral pigs in the Mediterranean agricultural region of Western Australia. Wheat and malted barley were again the preferred baits, there was a variable response to lupins, and commercial pig pellets were consumed least. There was minimal evidence of bait take by non-target species, and, where this occurred, it generally involved the consumption of the fermented wheat 1080 baits by kangaroos (*Macropus* spp.) and foxes (*Vulpes vulpes*). Six foxes were known to have been poisoned during the study with 1080-treated grain baits. Excluding foxes, no other non-target animals, including native species, were found dead during intensive searches for poisoned pigs (Twigg et al., 2007).

A disadvantage with 1080 is that the standard dose used for feral pigs—72 milligrams per bait—is very large. For instance, the standard dose of 1080 for wild dogs is only 6 milligrams per bait. Other disadvantages with 1080 include the risk of secondary poisoning of scavengers of pig carcasses, bait-shyness in pigs that receive sub-lethal doses, and the possibility of poisoned pigs vomiting (this can create a risk of secondary poisoning to scavengers eating the vomit) (Choquenot et al., 1996; Lapidge and Eason, 2010; Sharp, 2012e). However, studies of 1080 baiting in the Fitzroy River region found 1080-poisoned pig carcasses had full stomachs, and failed to find pig vomit despite searches around all pig carcasses, indicating that very few 1080-poisoned pigs in their studies vomited (Twigg et al., 2005, 2006).

Sodium nitrite has been identified as a new feral pig toxin. It is being developed by the Invasive Animals Cooperative Research Centre into a poison bait called HOG-GONE®, which utilises the existing PIGOUT® bait matrix. It has been field-trialled successfully in Australia and the USA (IVMS, 2010; Lapidge and Eason, 2010).

The development of sodium nitrite as a feral pig toxin will make feral pig control through poison both more targeted and more humane. Pigs are particularly susceptible to this compound, the symptoms it causes are moderate, and time to death is rapid. Sodium nitrite ultimately works by blocking the oxygen-carrying role of haemoglobin in red blood cells. The effect is to gradually deprive feral pigs of blood-borne oxygen, causing lethargy, rapid unconsciousness and rapid death (Lapidge and Eason, 2010). Sodium nitrite is also likely to reduce the rate of secondary poisoning in non-target animals and birds because:

- sodium nitrite and/or the HOG-GONE® bait matrix appears to repulse most marsupial species, including Bennett's wallaby (*Macropus rufogriseus*) and the Tasmanian pademelon (*Thylogale billardierii*)
- sodium nitrite doses required to kill are far higher than with 1080, so non-target species would need to consume more bait than with 1080 to receive a lethal dose

- sodium nitrite biodegrades very rapidly, thus making it unlikely that scavenging animals and birds will get a lethal dose from nitrite-poisoned pig carcasses
- sodium nitrite causes less vomiting in feral pigs than 1080, thus reducing a potential source of secondary poisoning.

6.6. Fencing

Fencing may be of value in some areas but it is expensive to erect and maintain. Electric fencing may have use for short-term control, for example to protect a small remnant plant population while regenerating. However, feral pigs seem to quickly recognise electric fences and will eventually crash through them if the incentive to reach food on the other side is sufficient. Standard fencing can be effective however if built robustly and regularly checked/maintained. Doupé et al. (2009, 2010) and Mitchell (2010) demonstrate fencing was effective in preventing severe feral pig damage to ephemeral tropical billabongs/wetlands, and protecting aestivating northern long-necked turtles from severe feral pig predation within these billabong/wetlands.

6.7. Use of dogs

Hunting with dogs is commonly used by recreational pig hunters. However, studies have shown that it is of limited value in reducing feral pig density on a large scale (McIlroy and Saillard, 1989) although dogs may be of value in removing solitary animals after application of a broad-scale management program (Caley and Ottley, 1995). Similarly, Burt et al. (2011) report some successful use of GPS-collared dogs and volunteer hunters when eradicating feral pigs in fenced conservation areas in Hawaii.

The success of hunting seems to vary with the amount of vegetation cover, the previous history of the pigs with dogs and hunters, and the skill and experience of the hunters. One study looked at the effect hunting with dogs had on the pig population in Namadgi National Park (Australian Capital Territory). Radio tracking of pigs, hunting dogs and hunters showed that only 27% of the pigs seen were captured by the dogs. In some instances, hunters passed within 100 metres of pigs without the dogs scenting the pigs. In this study, hunting with dogs only removed 13% of the pig population present (McIlroy and Saillard, 1989).

There are serious animal welfare concerns with the use of dogs, not only for the pig, but also for the injuries that dogs incur during hunting. Another concern is that hunting dogs that are not under proper control can readily disturb or attack non-target species, and simply scatter feral pigs, and hence be counter-productive with respect to control. The revised '*Standard Operating Procedure: PIG003: Ground shooting of feral pigs*' (Sharp, 2012c) offers detailed advice, including that "it is unacceptable to set a dog onto a feral pig with the intention of bringing it down, holding or attacking it."

6.8. Coordination with commercial harvesters

Commercial harvesting occurs mainly in northern New South Wales and southern Queensland. Usually, commercial harvesters of feral pigs operate where it is most profitable. Factors that affect the economic viability of harvesting include pig density, distance to abattoirs, ease of access for harvesters and chillers, disease and condition of the animals, and the attitude of landholders to their operations. Harvest also varies with market conditions and seasonal factors. Consequently, harvesting operations may not coincide with those areas where feral pigs are believed to be threatening native species and communities.

A study of harvest operations of feral pigs (for export to Europe) on numerous sites in southern Queensland found that harvest rates were typically low (<50%), well below replacement levels, and consequently populations would quickly recover. Harvesting was also biased towards larger animals, mostly (probably) males, because the price paid per kilogram of meat increases with the weight of the carcass (Gentle and Pople, 2013).

6.9. Habitat manipulation

There is limited opportunity to manage feral pigs by manipulating the habitat. One possible method is to take strategic advantage of the need for feral pigs to have access to water and cover from the direct sun in dry areas. For example, preventing access to dams, closing off open bore drains and removing essential cover. There is also the potential to restrict access of feral pigs to essential 'out-of-season' food sources such as crops when natural food is depleted.

6.10. Bio-control methods

The Pest Animal Control Cooperative Research Centre investigated the potential for the biological control of feral pigs using an immuno-sterility approach. The Cooperative Research Centre concluded that this approach was not feasible for a number of reasons, including:

- the unacceptable risk that such a method would pose to the domestic pig industry
- the fact that inducing infertility in pigs has proven very difficult by any method, including chemicals; pigs have proven to be one of the least susceptible animals to fertility disruption
- the prohibitive cost of research and development (Peacock, 2003).

Fertility control using bait-delivered fertility-controlling agents is also not viable for wide-scale control of feral pigs, primarily because there is no fertility-controlling agent available, and also because of the cost and difficulty of delivering any such fertility agent to a widely dispersed and highly productive animal (Choquenot et al., 1996).

A study by Quy et al. (2014) trialled a single-dose injectable immunocontraceptive vaccine (GonaCon™) on a small, localised feral pig population in woodland in the West Midlands region of England. This vaccine works by inducing the pigs' bodies to produce antibodies that targets and destroys the gonadotrophin-releasing hormone (GnRH), an essential hormone for reproduction. 10 sows and six boars were used in the trial, and effects of the vaccine were measured by bloody analysis and movement tracking. The vaccine had some effect in boars, while in sows, reproductive output was inhibited for 4–6 years. No obvious detrimental effects on physiology and behaviour were noted, and could be an appropriate control method for small populations where other control methods are not appropriate to be used. This technique is not applicable to feral pig control in Australia yet, given the feral pigs in this study had to be captured and injected by hand with the vaccine.

An Australian literature review of feral pigs impacts concluded that, despite recent international advances, fertility control is not likely to be available in a practical form for widespread use in Australia until anti-fertility drugs can be administered orally in a target-specific manner, and until fertility control can be demonstrated to produce consistent results in wild populations (Bengsen et al., 2014).

6.11. Animal welfare considerations

The need to consider the welfare of animals during animal control activities is now widely recognised. Each state and territory has animal welfare legislation that pest animal controllers are required to adhere to. Animal welfare groups and state and territory pest management agencies encourage well planned and coordinated strategies aimed at achieving a long-term reduction in the damage caused by feral pigs using the most humane cost-effective methods and strategies.

A national animal welfare code of practice that applies to feral animals, *Feral Animals and Livestock, Destruction or Capture, Handling and Marketing* was released in 1991 and updated in 2003 (SCAW, 1991; NCCAW, 2003).

The Model Code of Practice for control of feral pigs and the national Standard Operating Procedures for control of feral pigs and were revised in 2012, and are available online at www.feral.org.au/tag/pig-sop/ and www.feral.org.au/wp-content/uploads/2012/09/pigCOP2012.pdf respectively. These are supported by the Commonwealth, and are an important guide to all feral pig management and control activities.

6.12. Approved methods of control by state and territory

The following table provides details on the methods of control available for use in each state or territory. Included are approved baits, approved trapping methods, use of exclusion fencing, other available methods, and animal welfare requirements. This table compiled with information provided by states and territories and updated in 2014.

Table 1. Summary of approved methods of feral pig control by state and territory.
(Compiled by the Commonwealth Department of the Environment from comments and advice provided by state and territory agencies in June 2010. State and territory agency names updated and correct as at October 2014.)

Methods of Control—Approved baits	
Australian Capital Territory	PIGOUT® 1080 baits, which are registered for use in Australian Capital Territory, or grain bait using 1080 concentrate registered for use in Australian Capital Territory.
New South Wales	Grain, pellets and registered manufactured products (currently PIGOUT®) are the only approved baits for use with 1080 concentrate poison under the 'Pesticide Control (1080 Liquid Concentrate and Bait Products) Order 2010' issued by the Office of Environment and Heritage's Chemical Policy Unit. Grain and pellets must be fed in bait stations, not piled or trailed on the ground, except in paddocks where stock are not currently grazing.
Northern Territory	PIGOUT® 1080 baits, fresh meat baits with 1080 (if injected by Parks and Wildlife).
Queensland	1080.
South Australia	1080.
Victoria	Registered products.
Western Australia	PIGOUT® 1080 baits, which are registered for use in WA
Methods of Control—Approved trapping methods	
Australian Capital Territory	As per the national Model Code of Practice and Standard Operating Procedures for feral pigs. Trapping is also regulated by the *Animal Welfare Act 1992*.
New South Wales	Standard cage traps of various designs including silo traps or heart shaped traps and cage traps with a number of designs for trap doors are common. Portable traps that can be lifted in by helicopter are used by the Office of Environment and Heritage (National Parks).
Northern Territory	Can be undertaken by landowners.
Queensland	Mesh traps.
South Australia	Panel and silo traps used extensively on Kangaroo Island.
Victoria	Trapping can be carried out with traps allowed under the Prevention of Cruelty to Animals Regulations 2008.
Western	Trapping is extensively used and there are numerous effective trap designs available.

Australia	Trapping subject to animal ethics requirements. Traps should be built using designs approved by the Department of Agriculture and Food.
Methods of Control—Exclusion fencing	
Australian Capital Territory	–
New South Wales	Rarely used but may appear in heavily populated areas on the New South Wales north coast.
Northern Territory	Can be undertaken by landowners.
Queensland	–
South Australia	Some fencing associated with forestry plantations on Kangaroo Island.
Victoria	–
Western Australia	Fencing is used to protect *Reedia spathacea* in the south-west of WA, but is expensive and requires maintenance.
Methods of Control—Other methods	
Australian Capital Territory	–
New South Wales	Shooting. A Judas pig program is often undertaken by the Office of Environment and Heritage where feral pigs are captured, sterilised, radio collared and released to find companions. Feral pigs located by the 'Judas' are usually shot (by ground or air) and the Judas released to find the next mob. This method is particularly useful where there are low numbers of feral pigs and the terrain is very steep and difficult to traverse. There are approximately 30 staff from the Office of Environment and Heritage (National Parks) and Local Land Services that have undergone Feral Animal Aerial Shooting Team training, a system of intensive training and regular re-accreditation. There are a large number of aerial shooting activities undertaken in New South Wales each year by both private and government agencies. Feral pigs are the main animals targeted in these campaigns although goats, wild dogs and deer are also controlled. Funding for aerial shooting comes from private landholders, Local Land Services and Office of Environment and Heritage.
Northern Territory	Can be used if they meet the [Northern Territory] *Animal Welfare Act*.
Queensland	–
South Australia	Some aerial shooting in the far north-east of the Lake Eyre Basin as part of broader large feral herbivore control programs. Some ad hoc ground shooting. Primarily by landholders but some well organised recreational hunting teams used on private forestry land on Kangaroo Island.
Victoria	–
Western Australia	Some ground shooting operations in the Walpole Wilderness area, south-west WA.
Australian Government	Standard Operating Procedures for Judas pigs.
Methods of Control—Animal welfare considerations	
Australian Capital	Feral pig control carried out in accordance with national Model Code of Practice and Standard Operating Procedures and the [Australian Capital Territory] *Animal Welfare*

Territory	*Act 1992.*
New South Wales	As per the national Model Code of Practice and Standard Operating Procedures for feral pigs. Strychnine, warfarin and yellow phosphorus / CSSP are inhumane and are not approved poisons in New South Wales.
Northern Territory	Feral animal management may only be undertaken if it complies with the [Northern Territory] *Animal Welfare Act*.
Queensland	No specific state codes. Model Code of Practice for the Welfare of Animals: Feral Livestock Animals. National Model Code of Practice and Standard Operating Procedures.
South Australia	–
Victoria	Tools and practices allowed under the *Prevention of Cruelty to Animals Act 1986* and Prevention of Cruelty to Animals Regulations 2008.
Western Australia	The [Western Australia] *Animal Welfare Act 2002* and Animal Welfare Regulations 2003 apply to feral pig control activities.
Australian Government	Australian Animal Welfare Strategy (2008). National Model Code of Practice and Standard Operating Procedures.

7. Regulation and management

The regulation and management of feral pigs, including control activities, is the responsibility of the states and territories in which they occur. It is each state's and territory's legislation that establishes the pest status of feral pigs and management responsibilities and considerations. These may include:

- setting priorities for natural assets for protection from feral pigs
- ensuring regional biodiversity management plans include relevant actions on feral pigs
- providing appropriate support, awareness and extension services for private landholders, Indigenous land managers, government land managers and community groups such as Landcare on the impacts and management of feral pigs
- conducting relevant studies to quantify the environmental damage due to feral pigs
- contributing to cross-jurisdictional or national committees on managing pest animal damage
- updating and modifying feral pig management strategies as appropriate
- ensuring that all control methods used to manage feral pigs comply with state/territory or national codes of practice, standard operating procedures and regulations.

The role of the Australian Government on feral pig issues is primarily to:

- provide Australian Government recognition, under the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act), that feral pigs are a key threatening process to many Australian ecosystems, fauna and flora
- disseminate knowledge to the public and relevant stakeholders on feral pig impacts in Australia
- to assist states and territories in the planning and coordination of feral pig management, particularly with regards to ecosystems, fauna and flora of national environmental significance
- to distribute funding that may assist with feral pig management through established funding pathways

- provide funding towards the Invasive Animals Cooperative Research Centre.

The Australian Government undertakes direct management of feral pigs for lands under its direct jurisdiction, including Kakadu National Park and Defence lands.

7.1. The need for coordinated action

Feral pig populations and the environmental damage they cause are not confined to national parks. Approximately 87% of Australia's land and associated biodiversity lies outside of parks and reserves (Ritchie et al., 2013), often in private ownership. This, coupled with the high mobility of feral pigs and their high reproductive potential, means that managing the environmental damage due to feral pigs requires an integrated and coordinated approach, often across a variety of land uses. In most settings, plans to manage the environmental impact of feral pigs need to consider the concerns and needs of neighbours, particularly agricultural. Relevant stakeholders need to be identified early and be actively involved in the planning and implementation of the program. Identifying the range of issues and concerns about feral pigs and their management, including of those who use feral pigs as a resource, is an integral part of the process of designing a management program.

Cowled et al. (2009) suggests current management units for feral pig control are often small and inadequate. The authors studied feral pigs from a 500,000 km^2 region in the rangeland of south-western Queensland and north-western New South Wales. The population structure was determined through the use of genotyping, which revealed five sub-populations. These sub-populations were moderately differentiated and had relatively high migration rates. The study concluded that generally management units for feral pig control in the rangelands should take into account geographical size and geographical features, especially major rivers in low rainfall areas.

7.2. Additional stakeholders

7.2.1. Local Government/pest management agencies

Local Government has a range of functions, powers and responsibilities at its disposal to influence feral pest management—on both private and public land—as public land managers and as land-use planners. These include the power to place statutory controls on freehold land, implement pest risk control measures and act as a primary advocate for and coordinator of local community groups and interests. Local government also has a key role in translating the policies of Australian and state/territory governments into on-ground actions.

7.2.2. Community groups

Community groups can help reduce the environmental impacts of feral pigs by:

- ensuring control programs take account of local environmental plans and issues and, where appropriate, include best practice management
- assisting in identifying high priority areas for pig control
- cooperating and coordinating with government managers and other agencies and groups in strategic, coordinated control programs.

7.2.3. Private landholders (including Indigenous land managers)

Private landholders can help reduce the environmental impacts of feral pigs by:

- ensuring property management plans include best practice management of feral pig damage, where appropriate, but particularly in high priority areas with nationally listed threatened species and ecological communities
- cooperating with local/regional control programs
- providing input to local or regional databases on feral pig distribution and abundance.

7.2.4. Relevant State, Territory and Commonwealth legislation and practices

The table overleaf provides information on relevant state, territory, and Commonwealth legislation related to feral pigs and their status under this legislation. Agency and landholder responsibilities for feral pig control varies between states and territories and two sections of the table outline these responsibilities. Where cross-border arrangements are established, these are outlined, and finally, best practice requirements for feral pig control are listed. This table was compiled with information provided by states and territories in 2010 and updated in 2014.

Table 2. Feral pigs and relevant State, Territory and Commonwealth legislation and practices. (Compiled by the Commonwealth Department of the Environment from comments and advice provided by state and territory agencies in June 2010. State and territory agency names updated and correct as at October 2014.)

Relevant State, Territory and Commonwealth legislation	
Australian Capital Territory	*Pest Plants and Animals Act 2005* *Animal Diseases Act 2005* *Plant Diseases Act 2002*
New South Wales	*Rural Lands Protection Act 1998* *National Parks and Wildlife Act 1974*
Northern Territory	*Territory Parks and Wildlife Conservation Act 2006* *Animal Welfare Act*
Queensland	*Land Protection (Pest and Stock Route Management) Act 2002*
South Australia	*Natural Resources Management Act 2004*
Victoria	*Catchment and Land Protection Act 1994* Also: Governor-in-Council Order, 13 February 1997: Feral pigs and Pigs-Run-Wild (*Sus scrofa*) are declared established pest animals.
Western Australia	*Biosecurity and Agriculture Management Act 2007* *Animal Welfare Act 2002*
Australian Government	*Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) Also: *Agricultural and Veterinary Chemicals Act 1994* (Agricultural and Veterinary Chemicals Code 1994) *Quarantine Act 1908*, Quarantine Proclamation 1998 and Quarantine Regulations 2000 Australian Pest Animal Strategy
Feral pig status under State, Territory and Commonwealth legislation	
Australian Capital Territory	Declared Pest Animal under the *Pest Plants and Animals Act 2005*.
New South Wales	Declared Pest Animal under the *Rural Lands Protection Act 1998*.
Northern Territory	Feral Species under the *Territory Parks and Wildlife Conservation Act 2006*. Declared as a Feral Pest on the Tiwi Islands.
Queensland	Class 2 Pest Animal under the *Land Protection (Pest and Stock Route Management) Act 2002*.
South	Declared Animal under the *NRM Act 2004*.

Australia	
Victoria	Feral pigs and Pigs-Run-Wild (*Sus scrofa*) are Declared Established Pest Animals under the *Catchment and Land Protection Act 1994*. The current declaration under the Act was made by Governor-in-Council Order, and the Schedule for established Pest Animals was published in the Victorian Government Gazette, 13 February 1997.
Western Australia	Feral pigs are Declared Pests under the *Biosecurity and Agricultural Management Act 2007*.
Australian Government	Feral pigs are a declared Key Threatening Process under the EPBC Act 1999.
State/Territory agencies responsible for feral pig control and management	
Australian Capital Territory	Australian Capital Territory Parks, Conservation and Lands, part of the Department of Territory and Municipal Services. Department of Defence manage some areas of National Land within the Australian Capital Territory and are responsible for management of feral pigs on that land.
New South Wales	Local Land Services (formerly Livestock Health and Pest Authority). Office of Environment and Heritage (National Parks). Department of Primary Industries. Forestry Corporation of New South Wales. New South Wales Food Authority. The crown, including national parks, state forests and local government, is required "to implement control measures to the extent necessary to minimise the risk of the pest causing damage to any land".
Northern Territory	Department of Land Resource Management. Department of Lands, Planning and Environment. Department of Primary Industries and Fisheries—administers the *Animal Welfare Act*.
Queensland	Biosecurity Queensland, Department of Agriculture, Fisheries and Forestry. Department of National Parks, Recreation, Sport and Racing. Department of Heritage and Environmental Protection. All state departments responsible for state land must control—e.g. Department of Main Roads.
South Australia	Biosecurity South Australia, part of the Department of Primary Industries and Regions South Australia. Eight Regional Natural Resources Management Boards have responsibility for regional delivery of pest control programs. Department of Environment, Water and Natural Resources is responsible for pest control in protected areas and unoccupied crown land. Crown bound by the *Natural Resources Management Act* so agencies have direct land management responsibilities, e.g. South Australia Water, Forestry South Australia, Transport South Australia.
Victoria	The Department of Environment and Primary Industries has the overall responsibility for policy for invasive plants and animals in Victoria, as well as the management of invasive plants and animals on private land. As landowners, the Department of Environment and Primary Industries and Parks Victoria have responsibility for invasive plants and animals management on their lands.
Western Australia	As landowners Department of Parks and Wildlife have responsibility for management of declared pest plants and animals on their lands. The Department of Agriculture and Food administers the legislation relating to declared pests.

Australian Government	Australian Government agencies responsible for issues relating to feral pigs: Department of the Environment, Department of Agriculture, Department of Defence. Under the EPBC Act, the Commonwealth must implement the feral pig threat abatement plan to the extent to which it applies in Commonwealth areas. These areas include Commonwealth national parks. Kakadu National Park is the only Commonwealth park with feral pigs and the Department of the Environment is the responsible agency. Other areas covered by the threat abatement plan include Defence land. A Commonwealth agency must not take any action that contravenes a threat abatement plan. Where the threat abatement plan applies outside Commonwealth areas in a particular State or Territory, the Commonwealth must seek the co-operation of the State or Territory with a view to implementing the plan jointly. Department of Defence land with feral pigs: Victoria: Puckapunyal Military Area New South Wales: Singleton Military Area Queensland: RAAF Base Scherger, Townsville training areas, Lavarack Barracks (including Mt Stuart), Tully, Cowley Beach, Tin Can Bay, Shoalwater Bay Northern Territory: Training areas at Bradshaw, Kangaroo Flat, Mt Bundey and Yampi Sound and Delamere Range facility.
Landowner responsibilities for feral pig control	
Australian Capital Territory	Land owners (known as rural lessees in the Australian Capital Territory as all private land is held under lease) are responsible for managing feral pigs on leased land. The Land Management Agreement the leaseholder signs for the leased land will stipulate that pest animals (including feral pigs where they occur) should be managed as part of any coordinated programs occurring in that area for a particular pest species. This may include actions required under a Pest Animal Management Plan prepared for feral pigs under the *Pest Plants and Animals Act 2005* (see above). At this time there has not been any Pest Animal Management Plan prepared for feral pigs.
New South Wales	Statutory obligation for landowners to continually suppress and destroy.
Northern Territory	Declared as a feral pest on the Tiwi Islands, which means that in this location it is a requirement of landholders to actively manage feral pig populations.
Queensland	Section 77 of the *Land Protection Act* places the responsibility on the owner of land to take reasonable steps to keep the land free from feral pigs. Local governments are empowered under Section 78 to issue a non-complying landholder with a notice to control feral pigs, and a maximum penalty of $60 000 is applicable if they do not comply with this notice. The Act also provides for penalties for the feeding, release or illegal keeping of feral pigs.
South Australia	There is no enforced requirement for landholders to undertake feral pig control on their land.
Victoria	Section 20 of the *Catchment and Land Protection Act 1994* states: "In relation to his or her land a land owner must take all reasonable steps to prevent the spread of, and as far as possible eradicate, established pest animals."
Western Australia	Under the *Biosecurity and Agriculture Management Act 2007,* landholders are required to control feral pigs (declared pests) on their properties. Any control option used must be in accordance with the *Animal Welfare Act 2002.*
Australian Government	The Commonwealth must implement the feral pig threat abatement plan to the extent to which it applies in Commonwealth areas.
Cross-border arrangements and issues	
Australian Capital Territory	New South Wales National Parks and Wildlife Service are contacted prior to the annual Namadgi National Park feral pig management program in May to ensure coordination of any management of pigs occurring on adjacent National Parks and Wildlife Service estates.

New South Wales	Landholders with land either side of the Queensland border have difficulty understanding that control methods that are legal in Queensland such as 1080 meat baits are not legal in New South Wales under the New South Wales Pesticide Control Order for 1080 Concentrate.
Northern Territory	–
Queensland	No formal trans-border issues identified. Variation in control methods on either side of the New South Wales/Queensland border.
South Australia	There are ephemeral problems with feral pigs following flood events downstream along the Cooper and Diamantina Rivers. These pig problems require good cooperation on cross border feral pig control programs between South Australia and Queensland. There are similar issues on the River Murray with pigs moving downstream across the border into South Australia.
Victoria	Anecdotal reports of assisted spread by hunters from New South Wales.
Western Australia	No issues with adjoining states of South Australia and the Northern Territory.
Australian Government	Issues with cross boundary movement of feral animals between Department of Defence's Mount Bundey Training Area and Kakadu National Park are being addressed.
Best Practice Guidelines / Standard Operating Procedures / Codes of Practice	
Australian Capital Territory	Management is carried out in accordance with the national Model Code of Practice and Standard Operating Procedures.
New South Wales	New South Wales Department of Primary Industries has adopted the national Model Code of Practice and Standard Operating Procedures.
Northern Territory	Exotic Pest Animal Policy.
Queensland	Queensland Feral Pig Management Strategy.
South Australia	No South Australia-specific guidelines. South Australia follows the national Model Code of Practice and Standard Operating Procedures.
Victoria	Victorian Department of Primary Industries provides information to landholders about best practice management.
Western Australia	The Code of Practice for the Capture and Marketing of Feral Animals in Western Australia is supported by the [Western Australia] *Animal Welfare Act*. The Southern Feral Pig Advisory Group also has a code of practice for community groups.
Australian Government	Model Code Of Practice for the Humane Control of Feral Pigs and associated Standard Operating Procedures are supported by the Commonwealth.

THREATENED SPECIES, ECOLOGICAL COMMUNITIES AND AREAS/REGIONS

The Threatened Species Scientific Committee (TSSC) advises the Commonwealth Environment Minister on the listing of threatened species and ecological communities under the EPBC Act 1999. Since the commencement of the EPBC Act, the TSSC has identified at least eighteen nationally listed threatened species that are threatened by feral pigs, including:

- two mammals—northern bettong (*Bettongia tropica*) and long-footed potoroo (*Potorous longipes*)
- three frogs—white-bellied frog (*Geocrinia alba)*, orange-bellied frog (*Geocrinia vitellina*) and the southern corroboree frog (*Pseudophryne corroboree*)
- three birds—southern cassowary (*Casuarius casuarius johnsoni*), black-breasted button-quail (*Turnix melanogaster*) and eastern bristlebird (*Dasyornis brachypterus*)
- one fish—red-finned blue-eye (*Scaturiginichthys vermeilipinnis*)
- two turtles—hawksbill turtle (*Ereimochelys imbricata*) and flatback turtle (*Natator depressus*)
- eight plants—elegant spider-orchid (*Caladenia elegans*), salt pipe-wort (*Eriocaulon carsonii*), lesser swamp-orchid (*Phaius australis*), greater swamp-orchid (*Phaius tancarvilleae*), Northampton midget orchrid (*Pterostylis* sp. Northampton), Darwin palm (*Ptychosperma bleeseri*), majestic spider-orchid (*Caladenia winfieldii*) and reedia (*Reedia spathacea*).

The non-EPBC-listed bird species cotton pygmy goose (*Nettapus coromandelianus*) and the Burdekin duck (*Tadorna radjah*), have also been identified by the Department of the Environment as being adversely affected by feral pigs.

The Department of Environment's databases list 142 listed threatened species and ecological communities as being affected by feral pigs. In order to target feral pig management to key sites, such as from within the list of the high priority areas, it is necessary to identify which of the threatened species are significantly impacted by feral pigs. This may include examples such as turtles impacted by feral pigs eating their eggs, alpine bog destruction impacting on frogs, or specific plants being selectively eaten by feral pigs.

Mapping showing the number of threatened species and ecological communities impacted on, or potentially impacted on, by feral pigs within their current range is available at www.environment.gov.au/topics/biodiversity/invasive-species/feral-animals-australia/feral-pigs.

State and territory governments provided the following priority areas for feral pig control in 2010 as part of a review by the Department of the *Threat abatement plan for predation, habitat degradation, competition and disease transmission by feral pigs*. States and territories have identified 86 areas that are high in biodiversity, are impacted by feral pigs, and where pigs are potentially eradicable or are able to be reduced to a low level of impact (the 86 areas include 30 Victorian national parks).

Australian Capital Territory

1. Alpine sphagnum bogs and associated fens ecological community. Includes the Ramsar-listed Ginini Flats wetland complex within Namadgi National Park
2. White box–yellow box–Blakely's red gum grassy woodland and derived native grassland

New South Wales

3. Paroo River Wetlands
4. Kosciuszko alpine sphagnum bogs
5. Macquarie Marshes
6. Narran Lake
7. Lowbidgee Wetlands
8. Kanangra–Boyd and Yerranderie National Parks

Northern Territory

The Northern Territory is particularly focused on islands, where the likelihood of eradication or containment of feral pigs is very high.

9. Tiwi Islands
10. Cobourg Peninsula
11. Croker Island
12. Elcho Island
13. Arnhem Land (including around coastal areas)
14. Dhimurru and Laynhapuy Indigenous Protected Areas (IPAs)
15. Blue Mud Bay coastline extending around to and including Kakadu National Park

Queensland

16. Morton Island
17. Currawinya National Park, south-east corner of Bulloo Shire
18. Cape York: Cook and Arakuun Shires
19. Bowling Green Bay National Park near Townsville
20. Lake Eyre Basin rivers (e.g. Cooper Creek and tributaries, Georgina and Diamantina systems), Shires of Boulia, Diamantina, Barcoo and Bulloo and the far western portion of Quilpie Shire
21. Border Rivers Goondiwindi Shire
22. Wet Tropics

South Australia

23. Western end of Kangaroo Island
24. Chowilla Floodplain
25. Cooper Creek

Victoria

26. Murray Scroll Belt Bioregion
27. Chiltern–Mt Pilot National Park

28. Brisbane Ranges National Park
29. Lerderderg State Park
30. Kinglake National Park
31. Mount Samaria State Park
32. Johnson Swamp Wildlife Reserve.
33. Reedy Lake, Nagambie Wildlife Reserve
34. Mount Alexander Regional Park
35. Barmah State Park
36. Terrick Terrick National Park
37. Mornington Peninsula National Park
38. Burrowa–Pine Mountain National Park
39. Alpine National Park
40. Mount Lawson State Park
41. Little Bog Creek Flora and Fauna Reserve
42. Ewing Morass Wildlife Reserve
43. Alfred National Park
44. Croajingolong National Park
45. Snowy River National Park
46. Coopracambra National Park
47. Errinundra National Park
48. Holey Plains State Park
49. Cape Conran Coastal Park
50. Gippsland Lakes Coastal Park
51. Lake Tyers State Park
52. Mount Buangor State Park
53. Discovery Bay Coastal Park
54. Kings Billabong Wildlife Reserve
55. Hattah–Kulkyne National Park
56. Murray–Sunset National Park
57. Murray–Kulkyne National Park

Western Australia

58. Dongolocking reserves region, Shire of Wagin and Shire of Dumbleyung
59. Lake Bryde, Lake Grace Shire and Kent Shire Reserves
60. Lake Toolibin Nature Reserve
61. Wandering–Hotham Nature Reserve
62. State Forest areas of the South West of WA
63. Shannon National Park
64. D'Entrecasteaux National Park

65. Conservation areas covered by the Walpole Wilderness and Adjacent Reserves Management Plan #67
66. Lake Muir Nature Reserve and National Park including Lake Muir–Byenup Ramsar Site
67. Jane National Park Conservation areas covered by the Perup Management Plan #72
68. Blackwood River National Park
69. Forest Grove National Park
70. Location 83 National Park
71. Wellington National Park
72. Lane Pool Nature Reserve
73. Waterloo Nature Reserve
74. Kalbarri National Park
75. Lesueur National Park
76. Beekeeper's Nature Reserve
77. Moresby Range Conservation Park
78. Howatharra Nature Reserve
79. Oakagee Nature Reserve
80. Bella Vista Nature Reserve
81. East Yuna / McGauran Hills Nature reserve
82. Binda Hill Nature Reserve
83. Burma road Nature reserve
84. Badgingarra National Park
85. North Kimberley IBRA
86. Fitzroy Valley Catchment

(Feral pig impacts in Western Australia are not limited to these areas)

ECONOMIC IMPACTS OF FERAL PIGS

McLeod (2004) estimated feral pig damage, in terms of total, national, economic costs (i.e. crop damage, control costs), at approximately $106 million per year. McLeod (2004) also details of a study monitoring feral pig damage to banana and sugar cane production in north Queensland between 2000 and 2002 (Mitchell and Dorney, 2002). Damage was determined from interviews with land holders and farm inspections. Feral pigs caused, on average, direct economic damage of $1,800 per banana farm per year and $5,350 per cane farm per year. Feral pigs caused damage to 16,150 tonnes of sugar cane (valued at over $377,000) or 5.65% of the sugar crop. There was no significant relationship between pig activity and the economic damage they caused for either banana or sugar cane farms. The total costs of feral pig damage and costs of control averaged $4,100 per year for each banana farm and $10,600 per year for each cane farm (Mitchell and Dorney, 2002).

Gong et al. (2009) valued feral pig damage, in terms of economic surplus, at $9.19 million per year. This was broken down into $1 million for the lamb industry, $2.32 million for the wool industry, and $5.86 million for the grain industry. Gong et al. (2009) estimate production losses in the grain industry to be 1% at low pig densities, 2% at medium pig densities and 3% at high pig densities, and production losses in the wool and sheep meat industries through lamb predation to be 4% at low pig densities, 7% at medium pig densities and 9% at high pig densities.

However, feral pigs are also at times the basis of a modest harvest industry. Most feral pigs harvested are exported as carcasses or meat cuts to Europe, where they are marketed as ‘wild boar’, though a small quantity is also used in the domestic pet food industry. Thus feral pigs can also represent a source of financial earnings, as well as a source of financial loss. Commercial harvesting of feral pigs has been undertaken in Australia since 1980 (Gentle and Pople, 2013). Commercial feral pig harvesting operations are restricted to those areas of New South Wales, Queensland and the Northern Territory where feral pig populations persist despite harvesting and management programs conducted by landholders and government agencies (Gentle and Pople, 2013).

The export industry is volatile. ‘Wild boar’ export quantities have declined overall from 322,091 carcasses in 2001 to 75,056 carcasses in 2012. The 2012 exports added up to approximately 81 tonnes in weight and had an estimated value of A$8.95 million (ABARES, unpub. data, 2014). Competition from European countries and unfavourable international exchange rates have reduced demand for Australian product in recent years and caused reductions in numbers of feral pigs harvested and prices paid. The industry has also been affected by the closure of processing plants. In 2013 it was uneconomical to export ‘wild boar’ and very little export occurred (Gentle and Pople, 2013; ABARES, unpub. data, 2014; Gentle, unpub. data, 2014).

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APPENDIX A

Objectives of the *Environment Protection and Biodiversity Conservation Act 1999*

Objects of Act

(1) The objects of this Act are:

(a) to provide for the protection of the environment, especially those aspects of the environment that are matters of national environmental significance; and

(b) to promote ecologically sustainable development through the conservation and ecologically sustainable use of natural resources; and

(c) to promote the conservation of biodiversity; and

(ca) to provide for the protection and conservation of heritage; and

(d) to promote a cooperative approach to the protection and management of the environment involving governments, the community, landholders and Indigenous peoples; and

(e) to assist in the cooperative implementation of Australia's international environmental responsibilities; and

(f) to recognise the role of Indigenous people in the conservation and ecologically sustainable use of Australia's biodiversity; and

(g) to promote the use of Indigenous peoples' knowledge of biodiversity with the involvement of, and in cooperation with, the owners of the knowledge.

Content of threat abatement plans—*Environment Protection and Biodiversity Conservation Act 1999*

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 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 the 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 of 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 cooperation 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.

Content of threat abatement plans—Environment Protection and Biodiversity Conservation Regulations 2000

Part 7 Species and communities

Regulation 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.