DRAFT
Recovery Plan for the Tasmanian devil (*Sarcophilus harrisii*)

Department of Primary Industries, Parks, Water and Environment

Tasmania

Australian Government

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Cover photograph: Tasmanian devil, DPIPWE

CONTENT

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Important phone numbers

Save the Tasmanian Devil Program (STTDP) Hotline (for volunteering to help, reporting roadkills, sightings of diseased devils, advice on nuisance devils or reporting illegal culling)

(03) 6233 2006

FOX HOTLINE (for reporting sightings or signs of foxes)

1300 FOX OUT

(1300 369 688)

Abbreviations and acronyms

CBSG	IUCN Conservation Breeding Specialist Group
CVO	Chief Veterinary Officer
DSEWPaC	Department of Sustainability, Environment, Water, Population, and Communities
DFTD	Devil facial tumour disease
DIER	Department of Infrastructure, Energy and Resources
DPIPWE	Department of Primary Industries, Parks, Water and Environment
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth)
FEP	Fox Eradication Program for Tasmania
MHC	Major Histocompatibility Complex (genes that control immune responses)
NC Act	*Nature Conservation Act 2002* (Tasmania)
NRM	Natural Resource Management
STTDP	Save the Tasmanian Devil Program
TSP Act	*Threatened Species Act 1995* (Tasmania)
Uni Syd	University of Sydney
UTas	University of Tasmania
ZAA	Zoos Australia Association

1 INTRODUCTION

The Tasmanian devil (*Sarcophilus harrisii*) (Figure 1) is integral to the ecology of Tasmania. It is now the world's largest marsupial carnivore, since the larger species — the thylacine (*Thylacinus cynocephalus*) — became extinct in 1936. Tasmanian devils are endemic to Tasmania, having disappeared from the Australian mainland around 430 years ago (Archer and Baynes 1972), probably due to the arrival of dingoes.

From being considered common and stable 18 years ago, the species is now considered Endangered at both a national level (*Environment Protection and Biodiversity Conservation Act 1999*) and within Tasmania (*Threatened Species Protection Act 1995*). The Tasmanian devil population has declined dramatically over the last decade, due to a fatal, contagious cancer — devil facial tumour disease (DFTD or the disease). Signs resembling the disease were first reported in 1996 at Mount William National Park (north-east Tasmania), and it has since spread to over three-quarters of the State. Neither the disease nor devils are known to have died out in any locations.

In the past, Tasmanian devil numbers were limited by food availability, competition with other devils, cats, quolls (native cats) and eagles, loss and modification of habitat, culling, and collisions with vehicles. Many of these factors may now have a greater relative impact on the remaining Tasmanian devil population, as the number of devils is so low. The absence or even sustained diminishment of devils is likely to drastically change Tasmanian ecosystems, and would also affect ecotourism.

There is currently no known vaccination, treatment or way to detect the disease before clinical symptoms (tumours) occur. Ongoing research is attempting to find ways to diagnose and prevent the disease in the wild, but this research is complex, lengthy and has uncertain outcomes. In the meantime the only effective means of ensuring the survival of the Tasmanian devil is through a managed captive group of animals, called an ‘insurance population’. Methods to reduce impacts on the wild population of devils are also being tested; and the extant population is being monitored. This work is currently coordinated under the Save the Tasmanian Devil Program — a joint State and Australian Government funded initiative.

This Recovery Plan outlines the measures required to: maintain a disease-free insurance population; manage and protect Tasmanian devils in the wild; maintain the genetic diversity; and manage habitats to allow for the re-establishment of Tasmanian devils. This is the first Recovery Plan for the Tasmanian devil, and it has been influenced by the successes and challenges of the Save the Tasmanian Devil Program.

Figure 1: Tasmanian devil (photo ©Anaspides, Iain Williams)

2 SPECIES INFORMATION

2.1 Taxonomy and description

The accepted scientific name for the Tasmanian devil is *Sarcophilus harrisii* (Boitard, 1841). *Sarcophilus* is derived from the Greek for meat (or flesh) lover and the species is named after George Harris, the surveyor and naturalist who first described the species in 1808. The devil is the only extant (living) species in the genus *Sarcophilus*, although two others (*S. laniarius* and S. *moornaensis*) are known as fossils from the Australian mainland. The genus is part of the Family Dasyuridae, which contains all the Australian marsupial carnivores, including quolls, antechinus (marsupial mice), dunnarts, planigales and mulgara. The Tasmanian devil is the largest species in this family. The closest relative to the devil is the Eastern quoll (*Dasyurus viverrinus*), which is also now only found in Tasmania.

An adult Tasmanian devil is about the size of a medium dog, with a stocky frame and fore legs longer than the hind legs. The animal has a comparatively large, wide head with a short broad snout, on a thick neck. They are around 60 cm long and 30 cm high at the shoulder, with a 25 cm tail. Adults (two years and over) weigh 5–14 kg, with males larger than females. Devils have a black coat and most have white patches on the chest and rump, and sometimes on the shoulders and flank. They cannot run fast (sprinting at about 25 km/hour) but have great endurance and can maintain 10–15 km/hour for several kilometres (N. Mooney unpublished). However, they are best known for their slow, rocking gait. The fore feet have 5 long toes with non-retractable claws, 4 toes pointing forward and one slightly to the side, giving an unusual ability to manipulate food. The hind feet have 4 long, more rigid toes facing forward on a near rectangular foot pad. Their tracks look very different from dog tracks — the large pads make a squarer print, with the evenly-spaced forward toe pads much smaller than dog toe pads. When a devil is excited or stressed, their hairless ears may appear red, because they flush with blood; in extreme excitement their tail may stand up.

2.2 Conservation status

The Tasmanian devil population has declined rapidly in a very short period. In 1992 the species was described as Common (Strahan 1992) and Stable (IUCN 1992), and was not listed as threatened at State or national level. It was first listed nationally in 2006 as Vulnerable, and in 2009 up-listed to Endangered due to the continued population decline (TSSC 2009). The Tasmanian devil was listed as Endangered in Tasmania in 2008.

2.3 Ecology and behaviour

Tasmanian devils eat meat, mostly scavenging dead animals (carrion) such as wallabies, kangaroos, possums, wombats and sometimes other devils and quolls. They also hunt live prey, especially smaller animals — such as birds (including insecurely penned poultry), fish, frogs, insects and reptiles; and slow animals — such as wombats, possums, sick or poorly-mothered lambs, incapacitated sheep, and wallabies being weaned. Devils maintain bush and farm hygiene by cleaning up carcasses, thus reducing the number of blowflies. They also have an unknown, but probably substantial, role in controlling corbie grubs (*Oncopera* spp.) and other pasture pests (Guiler 1970), and may help control European wasp (*Vespula germanica*) numbers by quickly removing carrion. Their feeding may be restricted to one large meal every 4-8 days (Pemberton 1990). They have sharp teeth and extremely powerful jaws, which can crush bones.

Tasmanian devils are primarily nocturnal (active at night) in most of their range. They will come out during the day to sun bathe, but mostly rest in hollow logs, caves, dense vegetation, dens or burrows. If hot, they pant to reduce body heat, as they do not sweat

(Hulbert and Rose 1972). Devils may occupy several dens or resting sites and they change dens every 1-3 days (Pemberton 1990). Adult devils are faithful to particular den sites (Owen and Pemberton 2005), and maternal dens may be clustered together if there is limited soil suitable for burrows (D. Pemberton unpublished).

Tasmanian devils are mostly solitary, but do not defend territories. They have overlapping home ranges of 4-27 km^2 (Pemberton 1990). Some devils habitually use latrines. Within home ranges they travel an average of 8.6 km per night, spending 7.7 hours moving from den to den (Pemberton 1990), mostly using well-defined trails to find food (Guiler 1978). The extent of movement, and favoured food species, varies between sites (Guiler 1970). Occasional movements outside the home range can be as far as 50 km in a night (M. Jones unpublished).

Although devils are primarily solitary hunters (Owen and Pemberton 2005), multiple devils may feed on large carcasses, and all individuals in an area are connected in a 'social network' (Hamede et al. 2009). Some individuals play a more active role socially, but the gender and age class of the devils doing this can vary. Most mating occurs from February (late summer) to March (Jones et al. in press), but it can occur up until June (DPIW 2008a). Outside the mating season contact between females is more common than contact between males, while within the mating season some male-female pairs associate for longer than at other times of the year (Hamede et al. 2009).

Tasmanian devil vocalisations include snorts, whines, grunts, coughs, hollow barks, growls, shrieks and screams (hence the name 'devil'). These noises are mostly heard when many devils gather around a carcass to feed. Although the noise and displays are mostly bluff to establish dominance, when there are high numbers of devils in an area the biting rates at feeding increases. During feeding encounters juveniles are bitten more frequently, mostly on the limbs, while bites resulting in head injuries are more common in adults during the mating season (Hamede et al. 2008). These injuries occur when males fight, females defend themselves to avoid mating with smaller males, and males bite females on the neck during mating.

Figure 2: Tasmanian devil pups about 5 weeks old (around 2 cm) (photo Sam Fox)

Most females start breeding at two years of age and breed once a year, having an average of three breeding cycles in their life (Jones et al. 2007). Before the disease was recorded, reports of females breeding under the age of two were rare, and restricted to sites with good soil and plenty of prey (Jones et al. 2008). Pups (Figure 2) are born 21-31 days after mating, depending on whether ovulation is delayed. Like other marsupials, they give birth to underdeveloped young (neonates), which crawl into the pouch and attach to a teat. The pouch is backwards facing and contains two pairs of teats. The pouch starts as a circular fold of skin, and expands as the pups grow. Tasmanian devil milk is similar in composition to that of placental mammals, but contains more iron (Green 1984).

Tasmanian devil litter sizes average two to three pups, and pups within a litter can have different fathers (M. Jones unpublished). Across the population, the sex ratio of pups is usually equal (half males and half females). Pups spend about four months in the pouch, and are then left in a maternal den while the mother feeds, gradually extending their forays from the maternal den over the next few months until weaning. They are weaned mid-December to early February, at about nine months, and then permanently leave the maternal den. The young do not accompany the mother at night and she does not teach them to hunt (Jones et al. in press). Female young mostly stay close to where they were born and most males disperse further.

A high number of juvenile devils (up to 60%) do not survive to adulthood, but the reasons for this are unclear. Juvenile devils are similar to adults, except for being more agile — they can climb small trees and jump to a degree (a feature of adult devils is that they cannot jump upward). Young devils are potential prey for wedge-tailed eagles (*Aquila audax fleayi*) (Figure 3), masked owls (*Tyto novaehollandiae*) and spotted-tailed quolls (*Dasyurus maculatus*), and many are killed by poorly controlled domestic dogs. Previously thylacines would likely have been a significant predator of devils of all ages. Tasmanian devils compete with spotted-tailed quolls and may be the reason for low densities of spotted-tailed quolls in some areas (Glen and Dickman, 2005). Devils can live up to seven to eight years of age, but most only live to five to six years in the wild.

Figure 3: Tasmanian devil with prey and wedge-tailed eagle (photo Jackie Smith)

2.4 Distribution and abundance

Tasmanian devils occur throughout mainland Tasmania, and on two islands — Robbins (inshore) and Badger (offshore) (Figure 4). They occur naturally on Robbins Island, as at very low tides the island is linked by land to mainland Tasmania. In 1996 devils were deliberately introduced to Badger Island, by unknown persons. Tasmanian devils are thought to have occurred on Flinders Island in the early 1800s, as indicated by sub-fossils

(McCallum 2008b), and were present on Bruny Island when Europeans arrived (Medlock and Pemberton 2010).

Figure 4: Tasmanian devil distribution and approximate 'core habitat'
Core habitat is inferred from observations of high densities of devils prior to disease emergence. Habitat is patchy, so that there are patches of poor habitat within the shaded area, and patches of good habitat outside the shaded area: comprehensive data on the locations of these patches were not available

As devils occupy all terrestrial habitat within their geographic range, the extent of occurrence (or range) and the area of occupancy are the same — both 64 030 km^2 (Jones and Rose 1996). The total area of Tasmania in conservation reserves is 15 300 km^2, but none of this is actively managed for the Tasmanian devil. There have been no significant distribution changes in the last 10 years, and it is not known whether the disease will result in a contraction of the area occupied by devils via local extinctions.

Although devils from north-western Tasmania are genetically distinct from those found across the rest of the State, there is a small amount of movement of devils between the two groups (Jones et al. 2004). All wild Tasmanian devils are therefore considered to be part of a single population.

The average pre-disease density of devils in unmodified habitat across Tasmania was 0.3 to 0.7 devils per km^2 (M. Jones unpublished). In some modified habitats much higher densities can occur: up to eight devils per km^2 occurred for several years on Badgers Island; and local densities exceeded four devils per km^2 on some pastoral properties with low intensity stock management (N. Mooney unpublished). Tasmanian devils were more abundant in the north, which may have been due to the reliability of seasonal rainfall in the north, or cooler temperatures in the south (Jones and Rose 1996), and the influence of these factors on vegetation and/or prey species. The devil 'core habitat' (Figure 4) comprises the low to moderate annual rainfall zone of eastern and north-western Tasmania. This includes the eastern half of Tasmania, the northern coastal region, and a narrow strip down the west coast.

The Tasmanian devil population increased from the late 1960s through to the mid-1990s, and has since declined due to the disease. From 1992 (pre-DFTD) to 2009 there has been an 80% decline in devil sightings across Tasmania (DPIPWE unpublished). These figures are obtained from annual spotlighting systematic counts, and therefore can only be used as a rough guide. So far the decline has not ceased or slowed down. The Tasmanian devil has declined by as much as 95% at sites where the disease was first noticed (McCallum et al. 2007). In 1998 the population was estimated as 120 000 at its peak (post-weaning) (N. Mooney unpublished), and in 2007, the total population was estimated at around 20 000–50 000 (DPIPWE unpublished). Accurate estimates of current population size are not available; however, considering there has been an average decline in sightings in the annual spotlighting surveys of 16% since 2007, the best estimate of current population size is between 17 000–42 000.

The north-west is the only remaining area supporting high densities of devils where DFTD has not been detected. Whether extinction in the wild is likely depends on a range of unknown factors; however, no indication of local extinction has yet been observed. Models indicate that after the disease arrives, an area will lose all devils in 10–15 years (McCallum et al. 2007). However, these models need refining with more accurate data, given that devils have now been seen to persist at infected sites for longer periods.

2.5 Habitat

For marsupial carnivores, good quality habitat contains a combination of a year-round food supply, enough den sites for breeding and daily movements, and structural features for refuge and foraging (Jones et al. 2003). The habitat requirements of Tasmanian devils include:

- places to hide and shelter during the day, such as dense vegetation, hollow logs, burrows or caves;
- areas with open understorey mixed with dense patches of vegetation which allow hunting; and
- soil suitable for burrowing for maternal dens.

For devils, the combination of these features within the habitat is more important than the presence of any particular vegetation community or habitat type.

Suitable habitat includes all native habitats, forestry plantations and pasture (Jones and Barmuta 2000). Devils occur in two nationally listed threatened ecological communities; '*Eucalyptus ovata* - *Callitris oblonga* Forest' and 'Lowland Native Grasslands of Tasmania'. Modelling based on climatic criteria suggests most of Tasmania as potential devil habitat, with eastern and north-western areas more likely to contain devils in the absence of disease (Jones and Rose 1996) (Figure 4).

Preferred habitats include coastal scrub and sclerophyll forest (Guiler 1970), with predicted densities highest in mixed patches of grazing land and open forest or woodland, and in coastal heathland (Jones and Rose 1996). Grazing by sheep or cattle maintains short green grass that is attractive to macropods, the primary prey of devils (Jones et al. in press). Open forest, open woodland and scrub support high densities of prey and facilitate hunting. In addition, devils travel through lowlands and creeks, and favour other rich sources of food such as carcass dumps, open rubbish dumps and roads (Jones and Barmuta 2000).

Dense wet eucalypt and rainforest, alpine areas, dense wet heath and open grassland all support only low densities of devils (Jones et al. 2004). Devils also avoid steep slopes and rocky areas (Jones and Barmuta 2000), and do not occur in areas of extensive pasture with no natural vegetation (Guiler 1970). Habitat features, both natural (e.g. estuaries; steep rocky areas) and man-made (e.g. large tracts of cleared land with no patches of native vegetation), may influence the movement of devils through particular areas (Jones et al. 2004).

Habitat critical to the survival of the Tasmanian devil includes:

- all disease-free areas within mainland Tasmania with suitable devil habitat;
- all areas of the pre-disease core habitat; and
- areas that may be required under the recovery program for the future introduction of Tasmanian devils.

2.6 Threats

2.6.1 Primary threat — devil facial tumour disease

Devil facial tumour disease is a lethal, infectious cancer. In infected areas, nearly all animals over two years old, and some younger animals, contract the disease. It causes lumps or lesions (swollen, broken or bleeding areas) in the mouth, or on the face or neck. The lumps grow into larger tumours in, or just under, the skin (Figure 5).

Figure 5: Devil facial tumour disease in a Tasmanian devil (photo STTDP)

The tumours make it hard for the animal to eat (which makes the devil weak); they erode bone and soft tissue, and can spread to the liver, kidney and other organs. The latency period (between infection and becoming infectious) is thought to be around six months (McCallum et al. 2007), but could be up to 12 months. Latency could also vary between individuals, possibly relating to the number of cancer cells transferred, the location of the wound, and/or the genotype and immunological status of the infected individual (McCallum et al. in press). The stage of tumour development at which the disease can be transmitted is also unclear. There is no test to detect the disease prior to lesions and tumours appearing, and no cure. Treatments to excise the tumours and chemotherapy have not been successful. After lesions appear devils die in three to eight months (most within six months), from starvation and the breakdown of body functions.

The disease is spread by ‘allograft’ — where clonal cancer cells are transferred (Pearse and Swift 2006, Murchinson et al. 2010) when an infectious devil bites and injures a healthy devil. Spread via cancer cells shed into carcasses or by devils scavenging dead devils have not been fully discounted (Hamede et al. 2008), and the longevity of cancer cells in a carcass is not known. However, the cancer cells do not survive for long periods away from a host (unless in large lumps) (Lees 2005). Biting between devils occurs during aggressive encounters while feeding, mating, establishing dominance, and juvenile dispersal. There is no evidence of vertical transmission — from mothers to young (STTDP 2008b). As the disease relies on direct contact with the cancer cells (i.e. it is not airborne or insect spread) it is not highly infectious. However, because of social connections, the disease can spread to all devils in an area once one is infected (Hamede et al. 2009).

The cancer cells originate in the peripheral nervous system (Loh 2006a, Murchinson *et al.* 2010), but the cause of the original mutation is unknown. No links between the disease and chemicals have been found (Moore 2008, Ross 2008), and no viruses have been detected (Pyecroft et al. 2007). Until 1996 the disease had not been found in the Tasmanian devil (Loh 2006a, b), and it is not present in the devil’s closest relative the eastern quoll, or the spotted-tailed quoll (Hawkins et al. 2006). Only three other types of infectious cancer are known worldwide.

Even though the cancer cell genetics are slightly different to the devil’s cells, and Tasmanian devils have competent immune systems (Woods *et al.* 2007), the cancer cells do not provoke an immune response. This is due to a lack of diversity in the devils’ Major Histocompatibility Complex (MHC) — the genes that control immune responses (Siddle et al. 2007). The devils in the north-west have shown the same non-response as devils from the rest of Tasmania, and no devils with resistance to infection or natural immunity have been found. The disease has started changing (evolving) as it spreads, with 13 strains found, all derived from the original strain. This is important, as any resistance, treatment or vaccine may only relate to one (or a few) particular strains.

The disease is widespread across approximately 75% of Tasmania and in all land tenure and habitat types (DPIPWE unpublished). The affected area covers the previously high density devil areas of the devil core habitat, except the north-west and far west. Modelling of the pattern of spread conducted in 2005 (McCallum et al. 2007) supports the disease originating at a single location (Figure 6). The first case of confirmed DFTD was at Waterhouse in north-east Tasmania (Loh et al. 2006a). Spread across Tasmania is thought to have varied, with close localities sometimes having different disease arrival times. The rate of spread has been estimated as 7 km/year for one site (Freycinet Peninsula) (McCallum et al. 2007), but is thought to average around 7–10 km/year. The varied spread rates may be due to the habitat type, with faster spread through continuous forest habitat, or due to other unknown factors.

The disease has not reached the far north-west and west coast (Figure 6), but the spread west is continuing, with the disease front moving 15 km west since 2008. The most western location of the disease front is currently located to the east of the Murchison Highway close to Oonah. It is possible that DFTD will reach the north-west in 3–10 years (McCallum et al. 2007), but it is not known whether mortality will be as high in western devils, or whether western populations will react to the disease in the same way that eastern ones have.

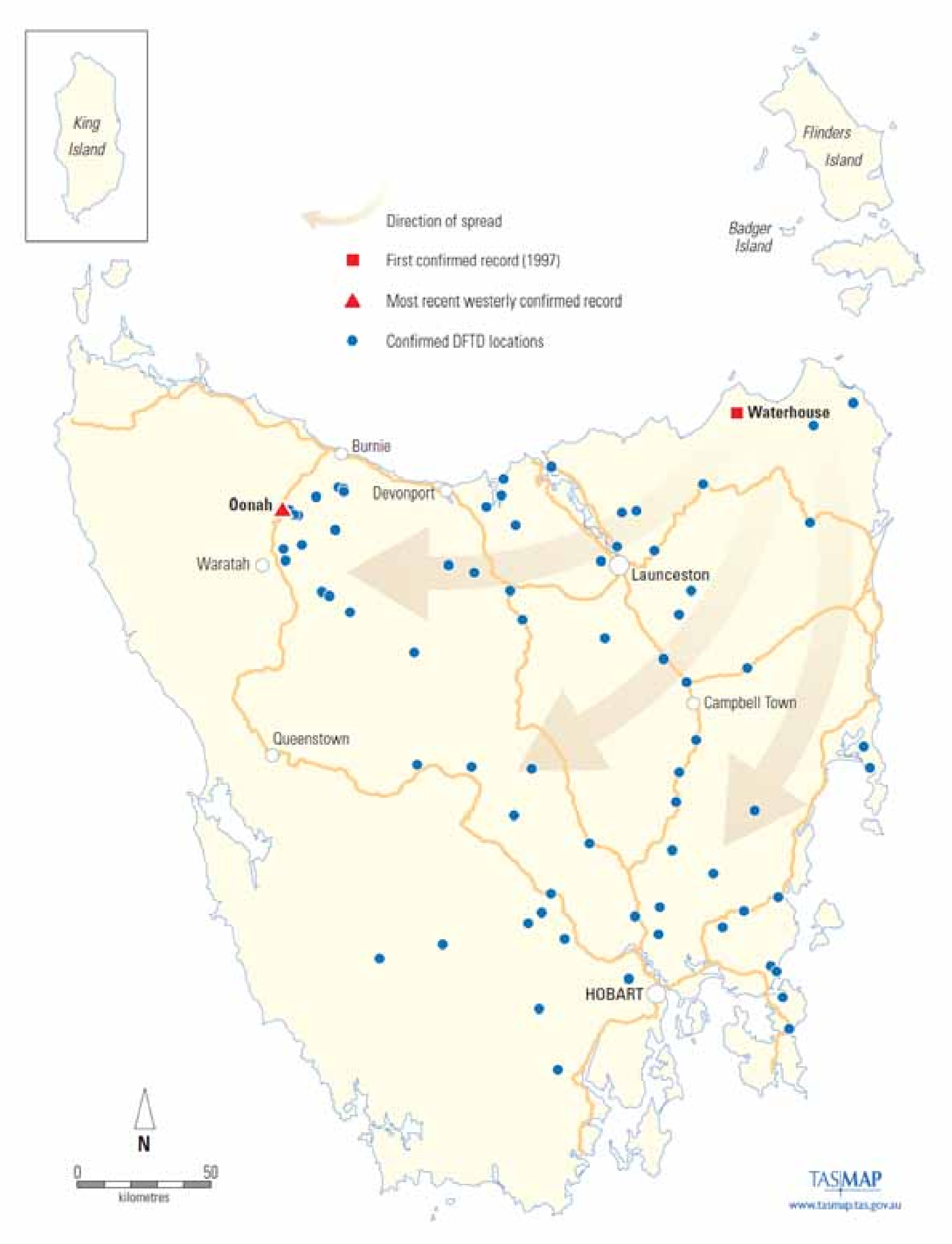

Figure 6: DFTD confirmed records and inferred direction of spread

The disease is associated with local devil declines of up to 95% (McCallum et al. 2007) in areas where the disease was reported earliest: north-east and central-east Tasmania. In infected areas the disease prevalence increases to 30–50% of devils in four years, and is maintained at that level (McCallum 2008b). In areas with high numbers of devil, disease prevalence has not slowed as the number of devils declines (McCallum et al. 2007; Lachish et al. 2009). If the affects of immigration to areas and emigration from areas are ignored, this could indicate that disease spread and persistence are not related to abundance. This pattern is typical of a sexually transmitted disease, and may be due to the increase in adults (who more often catch the disease) biting and injuring each other in the mating season (Hamede et al. 2008). This is important because these types of diseases can drive their host to extinction (McCallum et al. 2001, de Castro and Bolker 2005). However, no consistent seasonal patterns in disease prevalence have been found. This could be due to no pattern (i.e. spread is not related to mating season), or the masking of seasonal effects by variations in the latency (Hamede et al. 2009) or by devil movements. In addition, there are no data on disease prevalence for low density areas, so there is a possibility that disease spread could slow as devils decline further.

The disease is causing changes in Tasmanian devil population and life history patterns. The disease kills older animals first, then progressively younger devils, and only affects juveniles once the majority of adults have died (Lachish et al. 2007). The sex ratio and litter size in infected areas have not changed, but the average age of animals is mostly under two years, and diseased mothers (possibly in response to changes in their condition) have more female than male pups (Lachish et al. 2009). More of the younger (one year old) females are now breeding, which could be due to more rapid growth of animals in response to less competition for food (Jones et al. 2008). Unfortunately, these breeding responses are unlikely to lead to recovery, as mothers with the disease are unlikely to live long enough to raise their young, and few females are now producing more than one litter before they die from the disease.

Possible outcomes of the disease in the wild Tasmanian devil population include:

1. Local extinctions occur in the medium term, leading to extinction across Tasmania, possibly in 25-35 years.
2. Declines slow down, leaving patches of local areas with no devils and some with low densities of devils with the disease.
3. Effects such as evolution of the disease, a different response from the north-western devil subpopulation, climate, geographic factors, and/or social behaviour, may combine to prevent some areas from becoming infected.
4. Any or some of the effects listed in 3) above, possibly combined with increased or new threats e.g. devils being replaced by foxes, could increase the rate of decline in some or all areas — possibly leading to extinction in the wild in less than 25 years.

The list above demonstrates the many complicated and inter-related factors influencing the possible outcomes of the disease.

2.6.2 Other threats

The effects of other threats on the Tasmanian devil population are unknown, but are likely to be of lower impact than the Devil Facial Tumour Disease. The ‘pre-disease’ devil population sustained a relatively high mortality from factors such as roadkill, culling and possibly habitat loss. However, if the same levels of mortality are maintained in the depleted population, these factors may become more significant threats to the Tasmanian devil in some localities.

Lack of genetic diversity

The genetic diversity of Tasmanian devils, as measured by DNA sampling across their range, is very low compared to many Australian marsupials and placental carnivores (Jones et al. 2004). This is consistent with an island population descended from a small founder group, along with island effects and population declines in the past 150 years. Although survival and reproduction of Tasmanian devils is not compromised by this lower genetic diversity (Jones et al. 2004), low genetic diversity can reduce the disease resistance of a species (deCastro and Bolker 2004; Acevedo-Whitehouse et al. 2005). The lack of diversity in the MHC of devils is possibly one of the major reasons behind the spread of the Devil Facial Tumour Disease (Siddle et al. 2007).

Devils in the north-west and the east of Tasmania are genetically distinct. Gene flow between these areas (and possibly disease spread) may be reduced by habitat-related impediments to dispersal, such as extensive areas of unsuitable habitat (Jones et al. 2004), although these barriers are not impermeable. The north-west devils have a slightly different MHC to devils from the east (CBSG 2008), and some devils have differences in their Chromosome 5 (*AusVet* 2005). There is a small chance that some of these animals may be genetically resistant to the disease, but to date all animals tested during research have contracted the disease.

It is important to ensure that the current genetic diversity is maintained (in captivity, and if possible in the wild) and to ensure any genes conveying potential resistance are not lost. If the worst happens and all wild devils die, it is important that the captive population contains the maximum level of genetic diversity possible.

Competition and predation by foxes

The habitat preferences of the introduced European red fox (*Vulpes vulpes*) (Saunders et al. 2006) overlap heavily with those of Tasmanian devils. Foxes and devils are of a similar size and are likely to eat each other's young. They share preferences for den sites and habitat so will compete for both food and shelter.

Although foxes have occasionally been released or have accidentally arrived in Tasmania since early European colonisation, they did not become establish (Saunders et al. 2006). It is highly likely this was due to the pre-disease high abundance of Tasmanian devils. Since 2001, a variety of evidence (fox carcasses, footprints, blood, and scats with fox DNA or fox hair) indicates there is a persistent low level fox population in Tasmania (Parkes and Anderson 2009). Although the density of foxes is thought to be as low as one per 500 km^2, evidence of foxes has been found in all areas except the far south, west and far north-west (DPIPWE 2009a). Coincidently, most records are in areas where Tasmanian devils numbers were previously high, but have been greatly reduced by the disease, and evidence of foxes started appearing five to six years after DFTD began having its impact.

Due to their low numbers within Tasmania, foxes are unlikely to be currently affecting devils. However, Tasmania has the capacity to hold up to 300 000 foxes (Bloomfield et al. 2005), and if foxes become abundant they will replace most of the medium and large marsupial carnivores (devils and quolls). This represents an enormous risk to Tasmanian devil recovery, as foxes could prevent the re-establishment of devils.

Collisions with vehicles

Roads modify natural landscapes, create barriers or channels for wildlife movement, fragment habitat, and alter local topography and hydrology. These changes lead to increased food in the vicinity of the roadway: green grass for herbivores and roadkill for carnivores. The threat of being killed on roads does not appear to significantly affect populations of most common species; however it can affect larger species, those with small fragmented or declining populations, or those that regularly and repeatedly come into contact with the road. Local features affecting the amount of wildlife killed on Tasmanian roads include visibility (a combination of road curviness and undulation), roadside barriers and other restrictions on the ability of wildlife to move off the road (Shaw et al. draft manuscript).

Much of the core habitat for Tasmanian devils contains roads, and devils have relatively large home ranges and movements. Devils use roads for long-distance travel (Jones 2000). Roads are a source of carcasses, so they attract devils to feed. (Figure 7). Being black, devils are hard to see on dark coloured tarmac, particularly in wet conditions. At night they can get disorientated by headlights and often do not move quickly enough to avoid being hit by fast-moving vehicles. Most collisions are fatal for the devil. Although devils make up a small proportion of the total wildlife killed on Tasmanian roads, it was estimated that during 2001–04 approximately 3392 devils were killed on roads each year (Hobday and Minstrell 2008). A previous estimate for 1998 was 5000 per year (N. Mooney unpublished). However, there are indications that the total number of devils killed on roads is declining with the decline in the population (Jones et al. 2007).

Figure 7: Casualties of the road — Tasmanian devil and food (photo Nick Mooney)

In local areas where Tasmanian devil roadkill has been measured, the impacts on the number of devils have been high. Collisions with vehicles removed 50% of the local devils in 17 months after a dirt road was sealed at Cradle Mountain (Jones 2000). This was thought to be due to an average increase in vehicle speed of around 20 km/hour. Speed reduction measures have since reduced this kill rate. A 20% decline in devils at Freycinet National Park was recorded over 12 months during a drought, when prey species were concentrated on road verges (Jones unpublished). Increases in sightings of road-killed devils have also been noted at two sites where existing roads were sealed: Woolnorth Road — 400% increase (Simon Plowright unpubl. data); and Arthur River Road — 50% increase (G. King unpublished), when local devil numbers were stable to slightly decreasing (DPIPWE unpublished). Although these rates of death are high, devils persisted in these areas due to migration from surrounding areas that contained relatively high densities of devils.

Collision with vehicles is generally considered a low level threat to the species across Tasmania; however, in areas where devil numbers are already reduced, loss of a high number of individuals due to collisions with vehicles could contribute to a population decline.

Habitat loss, degradation and fragmentation

Since European settlement, devil habitat has been lost through clearing for agriculture, forest plantations, extractive industries and residential development, especially in eastern Tasmania. The level and type of effect clearing has on devils depends on whether patches of bush are left, and the type of land use. Habitat can be degraded through altering features of the vegetation or soil, or by adding chemicals to the environment. Processes that can lead to these changes include mining, farming and forestry practices, removal of native vegetation, changes in fire regimes, and domestic and feral herbivores. Mining or heavy forestry machinery can cause dens to collapse, and clear felling may remove features that make a den useable. However, stock grazing in areas with forest or woodland nearby can maintain short green grass that is attractive to macropods, which in turn provides a prey base for devils. Similarly, a combination of high levels of control of game such as deer and wallabies (leaving carcasses) and low intensity stock management (resulting in weak or injured stock), can greatly enhance an area for devils.

Clearing of vegetation can lead to fragmented landscapes, often resulting in open areas of introduced species containing small patches of native vegetation. These small patches are less resilient to weeds, fertiliser drift and other edge effects. The division of large areas of suitable habitat (e.g. by new roads or utility corridors) may also increase the impact of other threats, such as collisions with vehicles. Impacts on Tasmanian devils from habitat loss, degradation and fragmentation include: loss of cover for hunting and resting; decreased availability of food; increased contact with introduced predators such as cats and foxes; and increased disturbance from humans. These factors can decrease local devil density and lead to local extinctions.

Although habitat loss and fragmentation has been identified as possibly the most important conservation issue for marsupial carnivores (Jones et al*.* 2003), Tasmanian devils are thought to be less susceptible to this threat, as they are highly mobile and are generalists in terms of habitat preferences. However, in some areas the sites suitable for making dens are sparse, and if the dens are destroyed there could be a significant effect on the abundance of devils (Owen and Pemberton 2005). In areas where Tasmanian devil numbers are already reduced and females are producing only one litter in a lifetime, the loss of a cluster of maternal dens could cause a local impact.

Illegal culling

Legal and illegal culling of Tasmanian devils was common in the settled parts of Tasmania after early settlement, up until the early 2000s. In 1830, the Van Diemen's Land Co. placed a bounty on devils on their northwest properties: 2 shillings and 6 pence (25c) for males and 3s/6d (35c) for females, and trapping for fur was considered an important part of the 'rural scene' (Guiler 1982). This led to local declines in devil numbers, prior to the legal protection of Tasmanian devils in 1941. After this, the devil population gradually increased, eventually leading to clashes with farmers, with resulting persecution of the animals by leg hold, cage and pitfall traps, and strychnine, or later organophosphate poisons.

Although much of the perceived impact of devils was most likely due to the scavenging of dead or ill sheep (Guiler 1970), landholders who could demonstrate that devils were pests to their stock could obtain legal culling permits. However, most of the culling conducted was illegal. The number of permits increased until the early 1980s (Guiler 1982); while during the 1990s occasional permits were still issued, most with increasingly sophisticated restrictions developed from cooperative research with landowners claiming problems. In 2002, the Tasmanian devil was given full protection under the *Nature Conservation Act 2002* (NC Act).

Current illegal culling of devils is considered to be less than in the past, but can still be locally intense. In the mid 1990s about 10 000 a year were killed, the vast majority illegally; now it is likely to be only hundreds per year (N. Mooney unpublished) — although the only measures of illegal activity are through informants, public reports and convictions. Public reports are now infrequent and the last conviction was in 1998. Illegal culling is not considered a major threat to the whole Tasmanian devil population. However, where devil abundance is reduced in a local area, illegal culling may become a threat.

Climate change

Predicted world-wide climatic changes include temperature increases and changes to rainfall patterns, which in turn affect sea levels, water availability and storm events. Biodiversity may adapt to these changes in the long term if natural adaptation processes have time to occur, and if there is sufficient connectivity in the landscape and few other threats. However, evidence suggests the rate of climate change in Australia will be faster than the rate at which most species can adapt by migrating, and/or changing behaviour, physiology or form (Howden et al. 2003). It is also likely that ecological changes due to climate change will random, rather than constant and smooth transitions, and this limits adaptive responses and movements. In addition, for threatened species suitable habitat is usually limited, and other, often severe, threats may be operating.

Climate change models indicate that although the temperature in Tasmania will increase, it will be at a slower rate than for the global environment, and climatic changes may be relatively moderate to 2040. The predicted changes to climate in Tasmania by 2040 include (CSIRO 2006):

- changes in annual rainfall (increase in west and central areas, decrease in north-east);
- increased rainfall in winter and spring in all areas;
- increase in maximum temperature of 0.33ºC in the north-east;
- increases in wind speed in all areas; and
- changes in potential evaporation (increase in some areas and decrease in others).

Warmer weather will affect water availability and lead to increased storm events, and changed fire regimes (the timing, location and intensity of fires). Changed fire regimes may in turn result in landscape changes from extensive erosion (DCC and DEWHA 2008). All these factors can change the distribution, structure and productivity of vegetation, which will have flow-on effects on animals. It may also lead to erratic and increased pest, weed and disease problems. In the short term this is unlikely to affect the Tasmanian devil, but the long-term effects on Tasmanian ecosystems, including devils, are unknown.

The only approach at this time is to implement management designed to ease threats and maintain devil habitat (including connectivity between patches), as these actions may also enhance the devil populations' resilience to the impacts of climate change.

Ecosystem changes due to low Tasmanian devil numbers

Although the exact ecological function of the Tasmanian devil is not known, the primary functions of top-order predators, are well understood. Through their activities, these predators provide selection pressure for the evolution of physical characteristics and behaviour in prey species to avoid the predator; they control prey numbers through removing the weak, sick, very young and very old; and they influence the behaviour and numbers of smaller predators through competition. In the case of Tasmanian devils, they also help maintain bush hygiene and reduce blowflies and pasture pests, by scavenging on (thus removing) carcasses.

The removal of a top-order predator can have massive direct and indirect effects on an ecosystem (e.g. Sih et al. 1985; Schmitz et al. 2000). Long-term effects may include:

- changes in abundance of animals that are prey of, or compete with, the predator;
- changes in abundance of animals that may suffer flow-on effects;
- changes in browsing damage; and
- changes in aspects of wildlife health.

Ecosystem changes from the loss of devils are potentially wide-ranging and interrelated, and may in turn become a threat to re-establishing devils by changing the way the ecosystem functions. Potential effects include:

- establishment of foxes and increases in feral cats;
- increases or decreases in native scavengers and predators (e.g. quolls, raptors, ravens);
- changes in abundance of prey species (e.g. increase in large prey and decrease in small prey);
- increased carrion (dead animals) in the landscape, thus increased prevalence of other diseases and flies; and
- subsequent changes to invertebrate populations (including insects) and vegetation (Jones et al. 2007).

In particular, increases in introduced predators (foxes and feral cats) could: make habitat less suitable for Tasmanian devils; increase competition with native quolls; and increase the risk of introduced diseases and parasites. Foxes and cats are likely to cause changes in the abundance, including even extinction, of many other prey species, as has happened on mainland Australia (e.g. Saunders et al. 1995). An established fox population would put 77 native Tasmanian vertebrate species at risk of predation (Bryant 2001), including 12 listed threatened species (Parkes and Anderson 2009), and would cost the Tasmanian economy around $20 million per year (Saunders et al. 2006).

The threatened Tasmanian wedge-tailed eagle and other raptors could be positively affected by the decline of Tasmanian devils, through more food and less predation on young (N. Mooney pers. comm. 2010). The flow-on effects of these potential increases, and how these and other ecosystem changes may in turn affect devils, are unknown.

3 RECOVERY PROGRAM

3.1 Strategy for recovery

The strategy for recovery of the Tasmanian devil focuses on developing an *insurance population*, while trying to manage the disease in the wild and maintain their ecological function.

The strategy is to:

- Maintain and increase the disease-free captive insurance population;
- Minimise impacts from the disease and other threats in the wild (‘wild management’);
- Monitor the devils and their habitat, to clarify the disease distribution and impacts, and help determine threat management strategies (‘monitoring’); and
- Investigate the disease to determine how to fight it (‘disease investigation’).

The logic behind the recovery strategy is to act before it is too late, even though our knowledge of the disease and its impacts is incomplete (McCallum and Jones 2006). Efforts are being directed to the areas of greatest potential benefit to the ongoing survival of the species, and management is implemented in a way that allows success to be measured, so results can improve future actions.

3.1.1 Strategy for recovery — insurance population

For any threatened species, a decision on captive breeding is usually made using triggers (e.g. population declines, available habitat area, food resources, genetic diversity, or changes in threats). Captive breeding is initiated only if changes in these triggers indicate a very high likelihood that the population could go extinct in the wild. In 2005, the factors influencing the decision to create an insurance population of captive Tasmanian devils included:

- the existence of only two wild sub-populations of devils, neither of which is isolated from the other (i.e. all wild devils will be exposed to the disease);
- the lack of a diagnostic tool, treatment, vaccine or other preventative for the disease;
- no recorded natural resistance to the disease;
- the high risk of wild devils becoming extinct in the near future, given the above factors, rate of spread of the disease and decline of over 51% (Hawkins et al. 2006) of the devil population; and
- the small amount of time available to collect sufficient disease-free animals as potential founders from which to develop a genetically representative captive population.

The purpose of the insurance population is to insure against the possible extinction of Tasmanian devils in the wild, and to provide for the release of healthy devils to the wild at appropriate times, to maintain the species’ ecological function in the long-term. In order to accomplish this task the insurance population should: be DFTD free; represent the genetic diversity of the species; and wherever possible maintain the suite of associated flora and fauna (e.g. parasites, gut bacteria) and wild behaviour to facilitate reintroduction to the wild. The insurance population will be increased until it can sustain a ‘harvest’ of devils for release, and it will be maintained at this level. Protocols for release of devils back into parts of their natural range must be developed and tested. The insurance population will be maintained until such time as it is no longer required for future release of devils to the wild.

Although wild Tasmanian devils transferred to captivity have an initial stress response, most adjust to conditions in captivity in one to two months (Jones et al. 2005). However, past breeding records are inconsistent and poor for most institutes (DPIW 2008a). The aim is to transfer skills to all operators, increase capacity, and increase the knowledge of breeding biology and captive husbandry, as the insurance population expands. Knowledge and skills gained will be used to better manage captive devils, and where relevant to assist in management in the wild. For example, it is thought that for female devils, the age at first reproduction is determined by body size, which could explain why more young females are breeding where the disease has reduced the number of devils and thus reduced the competition for food. Monitoring of captive devils will help confirm this.

Two major restrictions on our ability to maintain a genetically diverse captive devil population are:

1. the relatively low genetic diversity; and
2. the relatively short life-span with less reproductive opportunities.

These factors affect the number of animals required as potential founders and the total size of the insurance population needed to maintain the genetic diversity of the breeding population. Animals are considered 'potential founders' of a captive population until they contribute genetic diversity to the population. Some potential founder devils will not become insurance population founders as they either have genotypes that are already represented, or they do not breed successfully in captivity. In order to maximise and retain genetic diversity, the genetics of all founders must continue to be represented in the insurance population over time. Insurance population devils will be bred so as to maximise and retain the current genetic diversity, rather than selective breeding for possible disease resistance, as these goals require different breeding strategies. However, experimental selective breeding for resistance may still form part of disease research activities.

Each isolated group of captive animals that is part of the insurance population is too small to retain genetic diversity and would suffer from long-term genetic deterioration (through genetic drift and other factors) without coordinated management. This means a 'meta-population' approach — where all groups of captive animals are managed in a coordinated manner — is required (CBSG, DPIPWE and ARAZPA 2009). This approach involves strategic movement of animals between groups within the insurance population to retain genetic diversity, control population size, and manage disease risk (STTDP 2007b).

In order to be genetically representative of the species the insurance population must contain at least 95% of the species' genetic diversity (STTDP 2007b). To maintain this genetic diversity for 25 years, it has been calculated that150 founder devils from as much of the geographic range as possible need to contribute genetically to the insurance population. This is while the total numbers are built up to an effective (or breeding) population of 500 (STTDP 2007b; CBSG 2008). To reach the breeding target, it was calculated in 2007 that the actual captive population (including pups, juveniles and non-breeding adults) must total 1500 if all are managed intensively (in zoos and wildlife parks), and up to 5000 if all are 'free-living' (in large enclosures or on islands) (STTDP 2007b). The target figures for both the total population and number of founders required will be re-calculated as knowledge of both the disease and captive management of devils is improved.

Intensively-managed animals are fed, housed, treated by vets for parasites and illness, and have breeding strictly controlled. Free-living animals live in a more natural state and are more at risk from parasites, disease, hunger, and social impacts, so a larger population of these is required to reach the breeding target. The Tasmanian Devil Insurance Population Strategy (STTDP 2007b) details how these figures are calculated, and further discusses founders, intensive management, enclosures and islands.

The insurance population will consist of a combination of animals in captive facilities and free-living areas. This is because:

1. Intensive management is much more labour-intensive and costly;
2. Existing captive facilities that are part of the insurance population will quickly reach their current capacities (circa 250); and
3. Free-living devils are more likely to retain the behaviours and local adaptations e.g. the flora and fauna (parasites etc.) associated with wild devils, which may be important in re-establishing devils and maintaining their ecological function in the wild.

Only through using both methods (intensive and free-living) can the goals of the insurance population be achieved in the timeframe required (CBSG 2008).

'Free-living' Tasmanian devils can be in large enclosures ('virtual islands') or on real islands. Establishing free-range areas is a high priority, but due to the complexities involved in planning and establishment, it is a long-term strategy. Little is known about managing devils this way, and practical aspects such as enclosure sizes, number and ratios of animals, den construction, animal welfare issues (for devils and other animals) and food sources, need to be addressed. Enclosure or island size and the intensity of management, dictate how many devils can be accommodated whilst maintaining genetic diversity, maximising breeding, and minimising excessive aggression. Other considerations are environmental effects, site ownership, social and political factors, monitoring, biosecurity, costs and values such as World Heritage values.

'Virtual' islands can include places that can be isolated from the disease, such as peninsulas. If suitable areas to be isolated are infected, all devils inside the area would need to be culled to remove the disease, before disease-free devils are released. If areas suitable for isolation are in disease-free areas, then translocation of captive devils is not required and within this recovery plan the action is considered part of wild management.

Offshore islands provide potential translocation sites, but in addition to the considerations above, their suitability, in terms of size, and the availability of habitat, food and water, must be established. Tasmania has around 300 offshore islands, but most are too small to support a viable unmanaged devil population (CBSG 2008). There is also opposition from some sectors of the community and some associated environmental risks, in creating devil populations on offshore islands. This is because, apart from the islands devils have been known to previously inhabit, they would be occupying 'new' areas not part of their known natural range, and existing cultural and natural values may be affected. Detailed evaluation of specific islands must include investigating potential impacts and strategies to minimise these before any introductions can occur, and approvals must be sought under relevant Tasmanian and Commonwealth legislation. Translocation proposals must include management approaches, including regular monitoring and contingency plans for potential outcomes (e.g. a population boom).

To minimise the chance of disease in any part of the insurance population the following strategies are applied:

- at least half the insurance population will be held in mainland Australia to distance the animals from any risk of infection from diseased wild devils;
- wild animals collected as potential founders are all juveniles with no penetrating injuries, and are quarantined for at least 18 months to ensure the latent period of the disease has passed;
- management of captive animals follows the Tasmanian Devil Captive Management Plan (Lees 2005) and is overseen by the Captive Management Group;
- any movement of devils between captive facilities follows the Risk Categorisation Guidelines for relocation of captive Tasmanian devils (DPIWE 2008b); and

- all captive management (and field work) follows Biosecurity Guidelines that include protocols for equipment, food, pens and field work (DPIWE 2008a).

Increasing the capacity of intensively-managed captive breeding facilities is a high priority; however these facilities are still likely to reach their maximum carrying capacity. Options to resolve this may include restricting breeding and removing older (post-breeding) and excess animals. Older devils are more susceptible to other diseases and do not contribute to the breeding population, and excess animals are those whose genetics are already over-represented within the insurance population. Options include: euthanasia; moving them to facilities outside the insurance population; and release into the wild. Breeding of captive devils will only be restricted if the target breeding population is exceeded, no further spaces are available, and release is not feasible.

Export of captive-bred Tasmanian devils to other countries will only be considered if it is necessary for species recovery e.g. if all suitable Australian captive (including free-living) options have had their capacity maximised and are full before the insurance population reaches its target size. The only devils currently held overseas are four animals at Copenhagen Zoo. Potential regions for export include New Zealand, the USA and Europe (CBSG 2008). All requirements in relevant Australian and overseas legislation would need to be met before any export could occur. Any re-importation of devils would also require meeting of strict legal requirements. One potential option is to use overseas captive facilities to hold old or excess devils that cannot be released, so that all spaces in Australian facilities can hold animals that are contributing to the goals of the insurance population.

3.1.2 Strategy for recovery — wild management

The priorities to manage threats to devils in the wild (in priority order based on the degree of threat) are:

1. manage the disease in the wild (infected and uninfected areas);
2. eradicate foxes; and
3. manage other threats if required, as indicated by monitoring.

These points are considered in turn in the following sections.

<u>*Manage the disease in infected areas*</u>

Management of any infectious disease in the wild is based on reducing the contact between infected and non-infected animals. In infected areas the options are:

1. cull only infected or susceptible animals (for moderately or less infectious diseases);
2. cull all individuals (for highly infectious diseases e.g. foot and mouth);
3. vaccinate uninfected animals;
4. treat infected animals; and/or
5. decontaminate the environment.

Most of these options are currently not feasible for the management of DFTD in Tasmanian devils: the disease is not highly contagious and the host is Endangered, so culling of healthy animals would not be appropriate (option 2); there is no vaccine or treatment (options 3 and 4); and there is no known causative agent that can be removed from the environment (option 5). Until a vaccine is developed and/or large numbers of captive healthy devils can be released, culling of infected animals is the only possible option for suppressing the disease and maintaining ecologically functioning numbers of devils in areas where the disease is present.

Important considerations in culling animals to suppress the disease in the wild are:

- devil movement and dispersal rates and the degree of site isolation;
- the disease latency and stage at which tumours become infectious;
- whether spread is related to population density (i.e. if there are less devils will the disease spread slow down?);
- what type of encounters increase spread and when;
- whether cryptic devils (those untrappable by conventional methods) provide a disease reservoir; and
- which animals infect other animals e.g. there may be certain age or gender classes of animals, or individuals, that are important in disease spread — called ‘superspreaders’ (Hamede et al. 2008).

Devil movements, site isolation and the latency and infectivity of the disease all influence the geographic scale and potential locations in which disease suppression may be successful. Given the spread of the disease to date, broadscale suppression is not possible. Spread is not related to high levels of devil density, so it is unlikely, but still possible, that the disease will ‘fade out’ as devil numbers decline. As no specific type of individual (sex or age class) has been found to have higher contact rates with other devils, there is limited potential to control the disease by targeting possible superspreaders (Hamede et al. 2009). In most trapping studies there are some animals that avoid traps — if this is a high proportion of the devils in an area there is potential for these animals to continue spreading the disease. If a high proportion of aggressive encounters are during mating, culling prior to mating could slow disease spread. Alternatively, if feeding in groups represents much of the aggressive contact, managing food sources may be an option e.g. carcass dumps, roadkill, open rubbish dumps and shot macropod carcasses (Hamede et al. 2008).

Trial results show that the disease may be suppressed to some extent through culling infected animals in relatively isolated areas. However, a severely depleted devil population could not be recovered using this method. It is not known whether improved trapping and diagnostic techniques and an increased effort in culling diseased devils can eradicate the disease. The major difficulty in achieving this objective is the number of cryptic (untrapped) devils in an area, as these animals can act as a disease reservoir.

Manage the disease in uninfected areas

For uninfected areas, the only option for combating DFTD is to try to prevent the disease reaching the area. Protecting disease-free areas before they become infected is therefore a high priority. Culling diseased animals or using barriers at the disease front would be extremely difficult, very expensive and highly unlikely to be successful in stopping the spread (AusVet 2005). These options are only useful in areas where there are limited access routes e.g. peninsulas and islands. Identifying disease-free areas that are feasible to isolate is a high priority. There are many social, political and logistical problems in trying to isolate areas, such as site ownership, environmental effects, costs, fence design, management and ongoing inspection and maintenance of barriers. Monitoring for, and potentially removing foxes, also needs to be incorporated into management. Having some understanding of devil movement patterns will help resolve whether large-scale fencing or other landscape barriers (e.g. unsuitable habitat, estuaries, cliffs) can be used to isolate disease-free areas.

Eradicate foxes

As described in Threats (section 2.6.2), although the current threat to the Tasmanian devil from foxes is low, the threat risk from an established fox population would be very high. In addition, eradication of foxes is unlikely once they become established. Eradication of foxes is therefore a high priority for devil recovery. Poisoning by 1080 (sodium monofluoroacetate) baiting is the only cost-effective broadscale method of fox control available (Parkes and Anderson 2009). Although Tasmanian devils have been observed taking 1080 baits, they have a much higher tolerance for 1080 than non-marsupial carnivores, possibly due to reduced metabolic rates (McIlroy 1981). At the dosage rate used, adults would need to eat many fresh baits within 2 days to be killed (Mooney et al. 2005). In addition dasyurids cannot find buried baits efficiently unless they rot (by which time the 1080 residues are usually very low), and persistence of non-diseased devils appears normal even after repeated baiting and eating of baits has been observed (Mooney et al. 2005).

Manage other threats

For all other threats (habitat loss, roadkill, culling, and ecosystem changes) the current risk is low relative to the threat from DFTD. Existing activities to measure and minimise these threats (see section 3.2) will continue, and management practices (section 3.5) involving these threats should continue, or be implemented if not underway. Public education and awareness, and monitoring of devils are the priority activities for these threats. Education and awareness is important in addressing habitat loss, roadkill and illegal culling. As the effects of the disease progress across Tasmania, potential ecosystem changes require investigation, in particular, the abundance of feral cats. More detailed knowledge of habitat requirements can be used to form guidelines to assist developers to take into account the needs of devil habitat in their planning. Detailed knowledge can also help to determine the potential impacts of development proposals. Additional targeted investigations and on-ground measures (e.g. cat control, vehicle speed reduction activities) are currently low priority.

3.1.3 Strategy for recovery — monitoring

An understanding of disease spread, infected areas, devil population dynamics, social organisation and other ecological factors is required to determine and evaluate management strategies for both the wild and the insurance population. Continued monitoring of devils at sites across Tasmania, using comparable methods, is required to inform adaptive management, and is therefore a high priority. Comparisons are needed between disease-free and diseased areas, and between the responses of eastern and western subpopulations.

Effective monitoring must be designed to answer the questions:

1. Where does the disease front lie?
2. Is there local extinction in an area?
3. Is a local group of devils reacting atypically?
4. Are devils present in an area?

Knowledge of the location of the disease front is essential for identifying areas that are uninfected for possible isolation, for calculating spread rates, and for monitoring effects of the disease in different areas. Any indications of local extinction or an atypical response e.g. resistance or recovery, need to be identified and investigated further. One problem is that it is likely that devils may not be detected in an area when they are present in very low numbers. This is important for wild management and possible re-introductions, as remaining animals could harbour the disease. Some areas may naturally contain no devils, and this is important for detecting natural barriers, assessing devil movement patterns and determining habitat requirements. It is also important for not mis-describing local extinction. Investigating the large-scale movement patterns of devils is a high priority. In addition to helping plan barriers to devil movement, this information could be used to help predict disease spread and increase the efficiency of monitoring.

3.1.4 Strategy for recovery — disease investigations

The highest priority investigations are ‘applied research’ which directly relates to actions to save the species (STTDP 2008b). The identified priorities, in order (based on links to management in the wild, possibility of success and timeline for possible results) are to:

1. develop a diagnostic technique;
2. determine latency periods;
3. investigate the nature of transmission;
4. investigate and map disease strains;
5. identify resistant genotypes; and
6. develop a vaccine capable of being delivered in the wild.

As discussed below, these investigations are interrelated, and as results become available they will feed into existing and future research activities.

Diagnostic technique

Diagnostic techniques are critical, as without them infected devils cannot be identified until tumours appear, and the absence of the disease cannot be confirmed. Animals do not spread the disease during the latent period, so being able to cull them before tumours appear would significantly reduce disease spread. Identifying diseased animals as early as possible would also reduce the quarantine period for potential insurance population founders. Possible disease markers could include antigens, disease-specific antibodies, and/or changes in tissue structure (e.g. hair and whiskers) (Pyecroft et al. 2007). Any test developed must be tested and validated before it can be applied. A test applicable in the field would be the most valuable to recovery efforts.

Latency periods

Knowledge of spread rates and latency periods is essential in assessing options to limit the impact of the disease in the wild. These factors affect the rate the disease reproduces and spreads. Higher disease reproductive rates means higher proportions of infected animals need to be removed to successfully suppress the disease by culling. Similarly, if a vaccine is developed, the proportion of animals that need vaccination is dependent on the reproductive rate of the disease. There is also limited evidence that the latency period may relate to the mode of transmission. Spread rates are measured during devil monitoring. Possible methods to measure latency include observing devils that have caught the disease in the wild, or measuring tumour growth and extrapolating back (although this assumes constant tumour growth).

Nature of transmission

Understanding the nature of transmission of the disease will assist in managing wild devils and quarantine facilities. Research questions include:

- the stage of tumour development that it becomes infectious;
- the number of cancer cells required to infect another devil;
- whether the site of a tumour affects transmission;
- the viability and infectivity of tumour cells outside devils; and
- the role of both the genotype and the status of the individual’s immune system in resisting infection.

Further investigation of contacts between devils is needed to determine if there is a type of encounter that is more likely to lead to disease transmission, and whether multiple devils feeding at one carcass or scavenging on diseased devils can lead to transmission. This information can be used in planning disease management activities.

Disease strains and resistant genotypes

If resistant animals can be identified or selectively bred, they could be released to breed and help build a disease-resistant wild population. High priority research includes:

- genetic screening for devils with higher genetic diversity, especially in the Major Histocompatibility Complex and chromosome 5 profiles; and
- identifying genes in the tumour and the devils that may be responsible for establishing the disease or for resistance. One problem is that the disease may change and evolve, so any resistance found might not continue. An evolved disease may become less or more viable and virulent, with subsequent changes to the impacts on devils, and use of any treatment or vaccine. Monitoring the evolution of the tumour into different strains and determining where these strains occur is therefore also a high priority.

Vaccine

As the cancer cells have the same form and genetics in different devils, it may be possible to prevent the disease via vaccine. One problem is getting the devils' immune system to recognise the cancer cells as foreign. This means finding: a detectable immune response; cellular targets for a vaccine; and a way to strengthen the immune response. A vaccine could be used to protect devils in the intensively-managed part of the insurance population, and captive-bred devils being released. However, in order to protect wild devils, including the young of any released devils, a method of vaccine delivery suitable for use in the wild is needed. If vaccination required multiple handling of an individual at specific time intervals (e.g. boosters), this would be extremely difficult in the wild.

A further problem is that vaccination can only suppress the disease if there is a big enough decrease in the number of susceptible animals within the population. As described above this requires knowledge of the reproductive rate of the disease: the higher the reproductive rate the greater the number of wild devils that need to be vaccinated and/or captive animals released, and the harder this becomes (McCallum et al. in press). The feasibility, advantages and disadvantages of a vaccine approach have been analysed by Woods et al. (2007).

Treatment

Treatment of the tumours is not feasible in the wild, but would be useful if there was a disease incursion in the insurance population, in addition to being used for research into resistance, transmission and vaccines. It would also alleviate ethical concerns with many experimental procedures (STTDP 2008b). Further identifying and testing possible treatments such as chemotherapy and surgical excision is a low priority.

Other research

Other investigations, e.g. further work on the original mutative agent; investigation of risk factors for the disease; research on devils to help understand why devils are prone to all cancer types, are not included as recovery actions. These are considered lower priority as they do not directly relate to wild management, are very expensive and do not have outcomes that are applicable in the broad-scale.

3.1.5 Strategy for recovery — co-ordination of recovery program

An adaptive management approach has been adopted to ensure that research results and action outcomes are used to prioritise and implement future recovery actions, and this will continue for the life of the Recovery Plan. The PHVA workshop participants agreed that the priority for project management was to "establish a Recovery Team as a matter of urgency" (CBSG 2008). A Recovery Team, or similar group containing appropriate expertise, will be formed to guide the implementation of the Recovery Plan, evaluate and review progress and direct future actions. The Recovery Team will work closely with the existing STTDP Steering Committee and expert working groups.

3.2 Previous and existing activities

Although there are still many gaps in knowledge, compared to 10 years ago there is now a wealth of knowledge, experience and insight into Tasmanian devils and the disease, and this expertise is increasing through current activities. These are described below.

3.2.1 Previous and existing activities — insurance population

A captive breeding program to establish a disease-free 'insurance population' began in 2005. Juvenile devils were collected during dispersal in disease-free areas. A total of 142 devils have been collected as potential founders of the population. After being quarantined, most were transferred to zoos on the mainland and some were maintained within DPIPWE facilities, to form the basis of the insurance population. Breeding rates in mainland facilities have exceeded expectations. In July 2010, the insurance population consisted of 278 animals (including juveniles) in Australia: 205 in 17 zoos and parks on the mainland; and 73 in Tasmanian facilities.

The current insurance population contains a relatively high level of genetic diversity, with the founder base being 111 animals. Annual evaluation includes developing new population targets and assessment of genetic diversity across the insurance population. Currently the Insurance population is maintaining 98.96% genetic diversity. Improved knowledge of DFTD transmission, in particular vertical transmission, means new founders can be taken from diseased areas and integrated into the insurance population under appropriate quarantine procedures. The current founder base has been analysed as sufficient to maintain the genetic diversity of the population at 95% over 50 years providing 4-8 new founders are collected every 3 years.

Expanding the insurance population is ongoing and includes:

- adding wild caught animals as potential founders, as required to maintain genetic diversity;
- breeding captive devils and moving them between facilities as required;
- increasing the capacity of existing facilities;
- recruiting suitable existing facilities to the program;
- setting up and populating free-range enclosures;
- assessing devils in other zoos and wildlife parks for their possible inclusion in the breeding program; and
- assessing islands for the possible release of devils.

The industry body for zoos and aquariums — Zoo and Aquarium Association (ZAA) — coordinates the captive breeding program on the Australian mainland, and DPIPWE manages the Tasmanian program. Various publications have been prepared including a *Captive Management Plan* (Lees 2005) and an *Insurance Population Strategy* (STTDP 2007b). The aim is to have a sufficient founder base from which to build up and maintain a healthy, viable insurance population for 25 years that is disease free, represents the genetic diversity of the species, and is able to sustain a harvest of healthy animals for release into the wild.

In July 2008 a 'Population and Habitat Viability Assessment' (PHVA) was facilitated by the IUCN Conservation Breeding Specialist Group (CBSG). This assessment included reviewing the *Insurance Population Strategy* and planning actions (CBSG 2008). Based on this assessment a 'meta-population' model for retaining 95% of the genetic diversity of the insurance population has been prepared (CBSG, DPIPWE and ARAZPA 2009). This Meta-population Framework:

- describes how the various components will be managed as one large meta-population;
- includes criteria for incorporating additional facilities and animals into the insurance population; and
- explains how the performance of the insurance population will be evaluated against long-term goals.

The CSBG has recently agreed to undertake independent yearly evaluations of the performance of the insurance population in meeting the goals of the Insurance Population Strategy and Metapopulation Framework.

A Risk Categorisation for relocating devils between captive populations (DPIWE 2008b), and Biosecurity Guidelines for managing devils in captivity and field trapping (DPIWE 2008a), have been developed. These are regularly updated to incorporate increased knowledge of the disease, in collaboration with the Chief Veterinary Officer (CVO) and ZAA. They have been distributed to wildlife park operators and zoos. All parks are being encouraged to adopt the recommended practices. To date the disease has been confirmed in only one Tasmanian wildlife park and technical support is being provided to this park. A policy on how to house and manage senescent (post-breeding) devils is being developed by DPIPWE and ZAA.

A small-scale re-introduction trial is underway, with orphaned devils released into the area they originated, and monitored to determine factors for successful re-introduction.

Free-range enclosure trials are underway (Sim et al. 2010). The first ‘Devil Island’ is an 11ha free-range enclosure on the Tasmanian east coast. Six female and five male devils were introduced in 2008, and in the first (2009) season they started breeding in specially constructed dens (Figure 8). Negotiations are underway to establish three more ‘Devil Island’ sites.

The PHVA workshop (CBSG 2008) discussed the social and environmental aspects of many offshore islands. The ‘Islands Working Group’ concluded that although the larger islands are more likely to be successful in terms of minimising management and maximising population size, smaller islands should not be discounted. DPIPWE is investigating the feasibility of releasing devils on offshore Tasmanian islands to create new disease-free populations. This includes developing a process to evaluate the risks and benefits to both devils and the natural values of islands.

Figure 8: Artificial den in free-range enclosure (photo STTDP)

3.2.2 Previous and existing activities — wild management

Disease management in infected areas

Intensive devil trapping and culling of infected animals took place from January 2006 to January 2010 on the 160 km^2 Tasman-Forestier Peninsula. This site was chosen as the disease had only recently arrived, and the connection to mainland Tasmania is via a man-made bridge and a canal. In collaboration with the Department of Infrastructure, Energy and Resources (DIER), DPIPWE are testing 'devil-proof' additions for the bridge. These include cattlegrid-like structures, and possibly water jets, spotlights and barking dog noises set off by sensors at devil height. Local land managers and a wildlife park are assisting in this activity.

Measurements of the disease prevalence were made before culling began, and ongoing results are compared to the Freycinet Peninsula where there is no culling. All legal and animal ethics requirements are strictly followed when trapping and removing devils. Within these restrictions the methods are adjusted regularly based on the latest findings. Diseased devils are identified via visual examination, followed by histological confirmation (until a diagnostic test is available).

Analysis of monitoring data in 2008 indicated that selective culling of infected individuals neither slowed rate of disease progression nor reduced the population-level impacts of the disease (Lachish et al. 2010). In addition, the disease level has fluctuated, as opposed to only decreasing. However, as of January 2010:

- a total of 226 diseased devils have been removed from the peninsula;
- the number of diseased animals remains low;
- infection rates, which were increasing during the first year, stabilised in January 2007;
- disease prevalence has fluctuated around 10% but has not been above 20% (in contrast to an unmanaged area, where prevalence is typically 30-50%);
- the number of devils declined for the first 18 months, then stabilised in July 2007 at 40% of the original total and has not declined since; and
- some older animals remain.

There is still a large group of devils on the Forestier Peninsula (100 individuals trapped per yearly field trip), and this group is probably still fulfils it ecological function. If a disease suppression program had not been initiated, by this stage (6 years after disease arrival) it is estimated that there would be as few as 20 devils. In other words, culling has not removed the disease, but has reduced the impact. Future options include maintaining this management in the long term to continue suppression, or increasing culling rates using refined techniques and focusing removal efforts prior to the breeding season.

Modified trapping techniques (equipment, placement and timing) will be tested to attempt to capture cryptic (so far untrapped) devils, and the number of trapping trips will increase. STTDP veterinarians are also developing rapid blood sampling and handling techniques for field use. Blood and hair sample screening is underway, so the devils can be identified individually, and once a diagnostic test is available, animals tested positive can be targeted for removal.

Disease management in uninfected areas

The use of 'large-scale fencing' or other landscape barriers (e.g. roads, rivers, mountains) to isolate disease-free areas is being investigated. One potential site is Robbins Island, which is only accessible at very low tides, and other sites include Woolnorth and Cape Sorrell (CBSG 2008). In 2009, DPIPWE commenced an assessment of Tasmanian devils in the Woolnorth region prior to fencing of the Woolnorth Peninsula. This includes assessing the number of devils, ages and ease of capture (for possible satellite tracking of individuals). Satellite tracking can help determine large-scale devil movement patterns, differences in movement patterns between age classes or sexes, and the degree of overlap of home ranges. These factors may be important in deciding the most appropriate location of fences to ensure the least impact on the local devils.

Fox eradication

Activities to eradicate foxes from Tasmania began in 2001 with an Incident Control System, progressing in 2002 to the Fox Free Taskforce. Activities are now conducted under the 10 year 'Fox Eradication Program (FEP) for Tasmania', coordinated by DPIPWE (DPIPWE 2009a). The aim is to eradicate foxes from Tasmania and prevent further incursion. The FEP includes detection through searches for evidence and public reports, monitoring and research to guide control actions, and fox control via 1080 baiting and follow up trapping and shooting. A 24 hour 'fox hotline' (1300 369 688) has been set up for reporting sightings or possible evidence of fox activity. Progress has included:

- an increased ability to detect foxes via scat searches and DNA tests;
- staff trained in monitoring and fox control;
- use of dogs for scat surveys;
- over 80 000 baits laid in areas of concentrated fox records (Saunders et al. 2006);
- planned baiting of around 600 000ha per year (Parkes and Anderson 2009);
- increased community awareness; and
- greater knowledge of the non-target risks of baiting with 1080.

The FEP was recently reviewed independently, with the conclusion that eradication is possible under a modified program (Parkes and Anderson 2009).

Management of other threats

Ongoing activities to measure and reduce other threats include the following:

- Staff from Parks and Wildlife Service Tasmania collect information on roadkill throughout the State, and public reporting of devil roadkill is being promoted.
- Road warning signs (e.g. Figure 9) have been erected on the Forestier Peninsula in an attempt to reduce roadkill of devils. Research into roadkill rates and fauna-sensitive road design is being conducted by DPIPWE and the University of Tasmania (UTas), and trials of potentially more effective methods to reduce roadkill are being undertaken by UTas and DIER.

Figure 9: Tasmanian devil road warning sign (photo STTDP)

- Fuel reduction burning and clearing guidelines for land managers are being developed by DPIPWE to minimise potential impacts of fuel reduction burning and clearing on devils and their habitat.
- Officers of Parks and Wildlife Service Tasmania are being consulted on how to minimise the impact of fuel reduction burning on den sites.

- Informal discussion regarding den management are being carried out between DPIPWE and Parks and Wildlife Service for Narawntapu and Mt William National Parks.
- DPIPWE are developing interim forestry management guidelines for the Tasmanian devil in consultation with the Forest Practices Authority (FPA). The FPA will use these as a basis for forestry prescriptions under the Forest Practices System.
- Advice on nuisance devils (e.g. denning under houses) is now provided through the STTDP devil hotline.
- Reports of illegal activities involving Tasmanian devils are referred to the Wildlife Operations area of DPIPWE for follow-up action.
- DPIPWE, UTas and the University of Sydney (Uni Syd) are studying potential ecosystem impacts due to the reduced Tasmanian devil population. Trapping surveys are used to assess changes to vulnerable species, and other factors being measured include the responses of prey species to declines in devil numbers and responses of small mammals to associated changes in the abundance of feral cats.

3.2.3 Previous and existing activities — monitoring

Although there has been sporadic, intense but localised research on devils for many decades, surveys specifically for DFTD began in 2003 with a state-wide snapshot survey (Mooney 2004) and monitoring by DPIPWE commencing in 2004. Data from trapping, spotlighting surveys, and public reports of road-killed devils are collated and analysed, to assess the impact and distribution of the disease. Long-term monitoring data from three sites has given a clear picture of the 'typical' response to the disease.

A devil monitoring strategy is being prepared by DPIPWE. This strategy will detail how the monitoring focus has shifted from annual trapping trips at these sites to monitoring many sites around the State using motion-sensing cameras. Remote camera monitoring uses an attractant, such as a dead wallaby, to lure devils to an area, and a passive infra-red system triggers the camera. The cameras record high quality images that allow field staff to recognise individuals by body-marks and scars, and they allow visual detection of animals with tumours. The cameras can be used to monitor remote hard-to-access areas, areas with low numbers of devils where trapping effectiveness is limited, and large areas where intensive trapping is too expensive and time-consuming. Although analysing camera data is time-consuming, cameras are cheaper in the long-term and more volunteers can be used to set them up. They can therefore be used to plan and limit trapping to the most useful sites for informing management. If initial monitoring using cameras indicates results different from the expected response (e.g. absence of devils, absence of the disease, or more older individuals), more intense monitoring using traps can be conducted.

Just before DFTD was found, PVC poly-traps (Figure 10) were developed to provide a less stressful environment and decrease the risk of injury for trapped devils (Mooney 2004). Conveniently, these traps also allow effective cleaning and disinfection. Other remote monitoring methods, such as static microchip readers and hair snares, are currently being trialled. All monitoring follows the Biosecurity Guidelines (DPIWE 2008a).

During September and October 2009, intensive focussed trapping was conducted in western Tasmania — between Burnie and Queenstown — to locate the disease front. Planned disease-front monitoring will increasingly use remote cameras, as described above, with trapping used to confirm any records of diseased devils to the west of the current front.

Figure 10: Tasmanian devil in PVC trap (Photo Nick Mooney)

3.2.4 Previous and existing activities — disease investigations

The disease research program is coordinated by the STTDP, with regular reviews of the research agenda, gaps, priorities and progress. Scientific scrutiny, covering knowledge of the disease and appropriate management priorities, have included an AusVet Animal Health Services technical workshop in 2005 (AusVet 2005), and a forum of scientists in 2007 (Jones et al. 2007). A Research Strategy has been prepared by the STTDP (STTDP 2008b).

In 2003, an investigating team was created to form a case definition for DFTD. The team included state diagnostic laboratories, in collaboration with other centres of disease research in Australia and overseas (Appendix 1). Disease studies have included pathology; molecular genetics; chromosomes; pathology; epidemiology; immunohistochemistry; experimental transfer of cells; searching for viral and chemical agents; investigating disease markers (Pyecroft et al. 2007); and investigating vertical transmission. Other ongoing activities include examination of dead devils, analysis of field and captive specimens, and laboratory support.

DPIPWE and CSIRO have analysed and mapped the rate of spread and modelled the likely year of emergence of the disease (McCallum et al. 2007). A site-specific model of Tasmanian devil population and disease dynamics, including rate of decline, has been developed in conjunction with Landcare New Zealand. Other modelling work is being carried out by the UTas.

UTas is attempting to develop a pre-clinical antibody diagnostic test and validation of a possible test has commenced. The test uses small blood samples and takes only three to four hours. Other diagnostic techniques being investigated include X-ray diffraction, infrared spectroscopy, chemical analysis and molecular studies, to determine whether there are detectable differences between whisker fibres or proteins in diseased and healthy devils. Recent genetic research has found a diagnostic marker (a specific marker which may be suitable for disease diagnosis) and identified a suite of genes relevant to pathology and transmission of the disease.

UTas and DPIPWE are investigating incubation periods and transmission of the disease. Field research on transmission has investigated contact rates between wild devils using proximity-sensing radio collars. Research into tumour evolution has isolated 13 strains of the disease, and is ongoing to provide an indication of the future viability of the cancer and likelihood of its transformation in wild devils. This will be important if resistance is found or if a treatment and/or vaccine are developed. Mapping of the strains is being undertaken by DPIPWE.

Devils with slightly different Major Histocompatibility Complexes have been tested, but no innate resistance found. Research is being conducted by UTas, DPIPWE and Uni Syd into the Tasmanian devil's immune system; potentially resistant genomes; and response to DFTD, including vaccine feasibility and breeding for resistance.

Investigations of the efficacy and use of treatments are being undertaken by DPIPWE, Uni Syd, oncology consultants and STTDP vets. This includes chemotherapy drug trials and looking for new therapeutic agents. The chemicals trialled to date have been unsuccessful — even at the maximum tolerated dose, there is no anti-tumour effect. A new chemical is currently being tested.

3.2.5 Previous and existing activities — co-ordination

The Save the Tasmanian Devil Program (STTDP) was formed in late 2003, after a workshop of scientists and animal health experts from throughout Australia met to discuss the devil's declines due to DFTD. The primary role of the program is to recover the Tasmanian devil population and maintain its ecological function, as detailed in the Strategic Plan (STTDP 2007a). Core activity of the STTDP is funded by the Australian and Tasmanian Governments and is overseen by a Steering Committee of governments, the UTas, non-government stakeholders and experts, according to a Business Plan (STTDP 2010)

Insurance Population (STTDP 2007b), Communication (STTDP 2008a) and Scientific Research (STTDP 2008b) strategies have been developed to guide and support STTDP activities. These strategies are reviewed and updated as necessary. In addition, the *Strategy for managing wildlife disease in the Tasmanian Wilderness World Heritage Area* (DPIW 2008b) recognises DFTD as a priority for active surveillance and management.

After the initial scientific workshop, expert advice on the disease and how to manage it was sought via AusVet in 2005 and a forum of scientists in 2007, and scientific expertise was coordinated through a Senior Scientist. A Scientific Advisory Committee (SAC) and Meta-population Advisory Committee (MAC) have since been established to provide specialist expert advice on components of the STTDP. The role of the SAC is to evaluate the effectiveness of scientific projects, and provide advice on the scientific resources and skills required. The role of the MAC is to oversee the insurance meta-population framework (CBSG, DPIPWE and ARAZPA 2009) and provide advice on managing the insurance population. This includes technical expertise from the DPIPWE/ZAA Captive Management Group.

3.2.6 Previous and existing activities — community education/communication

A Communication Strategy has been prepared (STTDP 2008a), and communication activities undertaken include:

- a Scientific Forum;
- formation of a Stakeholder Reference Group;
- a public lecture series in 2007 hosted by UTas;
- quarterly newsletters (e.g. Figure 11);
- an integrated website: www.tassiedevil.com.au (STTDP 2010);
- the STTDP hotline: (03) 6233 2006;
- presentations to community groups and schools; scientific presentations at conferences; and

- publications in refereed scientific journals.


SAVE THE TASMANIAN DEVIL.

THREE MORE ENCLOSURES

Figure 11: *Save the Tasmanian Devil* Program newsletter

Communication activities aim to:

- raise awareness of the threats to the Tasmanian devil and environmental impacts of loss of the devil;
- foster collaboration, cooperation and support; facilitate input and participation by stakeholders; and
- convey recovery program information.

The STTDP hotline has been set up as a single point of contact for anyone wanting to volunteer to help, for advice on nuisance devils, and for reports of road-killed devils, sightings of diseased devils, or illegal culling.

An education and awareness campaign has been launched on devil roadkill. This has included information, postcards and posters in prominent places, such as Spirit of Tasmanian Ferries, hire car companies, and the Royal Automobile Club of Tasmania (RACT) newsletter. The key messages of this program are to reduce and report roadkill. The location of road-killed devils should be reported to the STTDP hotline.

A number of charities are raising money for Tasmanian devil conservation. The Save the Tasmanian Devil Appeal was launched in 2003 to fund research activities, and in 2009 was broadened to also fund management and community activities. Public interest in the plight of the devils has grown and increased support for the devil is reflected in public fundraising, the number of volunteers involved in the STTDP, and changes in attitudes toward human interactions with devils.

Volunteers are vital to the Tasmanian devil recovery effort and are involved in a range of activities, including reporting diseased and road-killed devils, looking after orphaned devils, and assisting in enclosure set-up and management, surveys, research and monitoring.

3.2.7 Previous and existing activities — legislation

Under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) any person proposing to undertake actions which may have a significant impact on listed threatened species (including the Tasmanian devil) should refer the action to the Minister for Sustainability, Environment, Water, Population and Communities. The Minister will determine whether the action requires EPBC Act assessment and approval. Administrative guidelines are available to assist in determining whether an action is likely to have a significant impact (DEH 2006). This legislation also regulates the international movement of Australian wildlife. Further advice on the EPBC Act is available on the Department of Sustainability, Environment, Water, Population and Communities website (DSEWPaC 2010a).

Under the Tasmanian *Threatened Species Protection Act 1995* (TSP Act) it is an offence to do any of the following unless in accordance with a permit:

- knowingly take, trade in or keep a threatened species;
- disturb a threatened species on land subject to an interim protection order;
- disturb a threatened species contrary to a land management agreement;
- disturb a threatened species that is subject to a conservation covenant under the *Nature Conservation Act 2002* (NC Act); or
- abandon or release a threatened species into the wild.

Similarly, the NC Act requires a permit to take, buy, sell or have possession of any form of protected wildlife, which includes the Tasmanian devil, or the products of such wildlife.

In addition to a range of voluntary mechanisms and options, the TSP Act provides for a number of formal instruments to conserve threatened species including Recovery Plans. Further information on the TSP Act is available on the DPIPWE website (DPIPWE 2009b). In Tasmania, a permit is required to import or export wildlife to/from interstate.

In 2006, the Devil Facial Tumour Disease was gazetted under the Tasmanian *Animal Health Act 1995* as a List B notifiable disease. These are diseases are known to occur in Tasmania and some form of monitoring or control is required. The Act requires people to report any case or suspicion of the disease to DPIPWE, via the STTDP hotline (03) 6233 2006, or the all hour emergency disease hotline 1800 675 888.

To carry out research on live vertebrate animals in Australia, an institution must be licensed and proposed projects must be approved by an Animal Ethics Committee (AEC). To be licensed the institution must agree to comply with the approved Code of Practice: *The Australian Code of Practice for the Care and Use of Animals for Scientific Purposes* (NRHMRC 2004). The code describes the responsibilities of: AECs; people who use or supply animals for research; and accredited research establishments. It requires that the welfare of the animals is always given consideration as a top priority, and that animal use in research must be: valid, humane, justifiable, and considerate. All use of live Tasmanian devils for scientific purposes must comply with the Code.

In Tasmania, animal welfare is regulated under the *Animal Welfare Act 1993*, which: defines animal research; governs the conduct of animal research; and legislates penalties for research by unlicensed institutions or researchers. AECs are operated by UTas and DPIPWE. Both DPIPWE and UTas have additional guidelines for the use of Tasmanian wildlife in research, including reporting requirements and provision for inspection of the research activities. A scientific permit is also required for any research involving the investigation and study of protected wildlife in Tasmania. This is managed separately and AEC approval does not guarantee a scientific permit. Permits are only issued after the DPIPWE requirements (DPIPWE 2010) are met, and all new permit applications are subject to public comment. A standard requirement of all permits is that of mandatory reporting.

The *Nature Conservation Act 2002* governs the keeping of wildlife in Tasmania, and a licence is required to keep Tasmanian devils in captivity, and to exhibit them (Wildlife Exhibition Licence). In addition, the Threatened Species Protection Regulations 2006 require anyone holding certain threatened species (including the Tasmanian Devil) to hold a ‘Permit to Deal with a Listed Taxon’. DPIPWE policy also requires that all species held under a Wildlife Exhibition Licence have an approved Species Management Plan and meet requirements under relevant Codes of Practice. Similar legislation and policies apply in other Australian states.

All recovery program activities will meet all the above legislative and protocol requirements.

3.3 Recovery objectives and performance criteria

The overall objective of the recovery program in the long-term (25 years) is to improve the conservation status of the Tasmanian devil and maintain its role in the ecosystem, through stabilising and recovering the devil population.

Specific objectives within the next 10 years are to:

1. Maintain a Tasmanian devil population in the wild, through managing the impact of devil facial tumour disease and minimising the impacts of other threats;
2. Maintain the genetic diversity of the Tasmanian devil; and
3. Establish a sustainable disease-free insurance population for possible future release into the wild.

The criteria that will be used to assess performance of the recovery program against the objectives, from the time the plan is adopted, are:

1. Persistence of devils in at least 90% of diseased sites monitored on an annual basis after five years; and persistence of least 70% after 10 years.
2. At least three disease-free areas containing Tasmanian devils isolated in the wild, through fencing or other barriers, within five years.
3. 95% of the genetic diversity of Tasmanian devils maintained on an ongoing yearly basis.
4. A healthy insurance population, that is disease-free and genetically representative of the species, across all bio-secure facilities, built up to a total population size of 450 within five years.

The above performance criteria are based on outcomes that are measurable and realistically achievable within practical timeframes:

1. The measures of devil persistence and associated timeframes are a better scenario than that predicted for devil persistence in the presence of the disease (see *2.6.1 Primary threat — devil facial tumour disease*). Given the uncertain outcomes of disease impacts and management options, accurately predicting the number of devils that may be maintained across Tasmania is not possible. Persistence is defined as devils being confirmed to be present in the monitored site. Presence at each monitored site is a simple and cost-effective measure compared to determining the abundance of devils across the full geographic range of the species.
2. The five year timeframe is a realistic time within which the goal may be achieved and still be useful. Using fencing or other barriers requires consultation, planning and construction, all of which mean a considerable lag time before any areas can be isolated. Alternatively the timeframe is restricted by the need to isolate areas before the disease reaches them, which depends on the locations chosen and variable spread rate (see *2.6.1 Primary threat — Devil Facial Tumour Disease*). The size of areas and number of devils enclosed are not specified, as these aspects can not be determined at this stage, however within the timeframe of disease spread and other restrictions (see *3.1.2 Strategy for recovery — wild management*) the areas and number of devils isolated will be maximised.
3. Retaining 95% of genetic diversity is the goal of the insurance population (see *3.1.1 Strategy for recovery — insurance population)* and is realistic as some diversity will be lost through a number of generations regardless of the breeding strategy applied. If possible, genetic diversity in wild devils will be maintained through recovery actions to maintain wild devils, but in the short-term this cannot be

guaranteed, and it would be very time-consuming and costly to measure. Monitoring genetic diversity of the insurance population is part of the captive management activities. The timeframe is ongoing, as the maximum genetic diversity can only be maintained in 10 years if that diversity is captured at the start of the program.

4. An ‘effective population’ of 500 from 150 founder devils is the goal of the current insurance population (see *3.1.1 Strategy for Recovery — insurance population*). The time in which the insurance population can be built up, founders added, and the total population size which can be reached, are restricted by the time for potential founders to contribute genetically, devil breeding and mortality rates, biosecurity requirements, and the planning and construction of facilities.

3.4 Recovery actions

The most appropriate actions for Tasmanian devil recovery were determined using current knowledge of the threats and available abatement strategies. Within this list, the tasks are ranked as High, Medium or Low priority, based on the current degree of threat, likelihood of success, timing of outputs and contribution to recovery objectives. The current intent is to implement all recovery tasks. However, the implementation, and relative priority, of any action or task may change in the next 10 years, due to the need for feasibility assessments, and the many uncertainties on the treatment and impacts of the disease. Actions and priorities will be regularly reviewed throughout the recovery process and additional tasks included if required. For example additional actions to minimise roadkill and habitat impacts are currently Low priority; however, if the relative impact of these threats increases these tasks would become a higher priority.

Action	**Priority of Tasks**
1. Maintain and manage insurance population	All High
2. Manage DFTD in the wild	All High
3. Monitor Tasmanian devils	All High
4. Conduct disease investigations	5 High, 1 Low
5. Manage other threats	1 High, 1 Medium, 2 Low
6. Research and measure habitat variables	2 Low
7. Coordinate recovery program	All High
8. Communicate with the community and stakeholders	All Medium

Action 1: Maintain and manage the insurance population

This action involves increasing the number of devils in the intensively-managed facilities managed as part of the insurance population, establishing free-living groups of devils in enclosures, and managing the insurance population. Tasks include:

a. Develop and implement integrated Management Plans for all captive Tasmanian devils held at different locations (High);
b. Collect more wild and captive potential founders, breed and move insurance population members, as appropriate, to increase the population and maintain genetic diversity (High);
c. Recruit and increase the capacity of suitable existing facilities in Tasmanian Wildlife Parks and ZAA zoos, and if required export captive devils to suitable overseas facilities (High);
d. Establish disease-free devil groups in large free-range enclosures on mainland Australia and in Tasmania, including (with effective barriers) disease-free sites on the west coast (High);
e. Investigate the feasibility and limits of releasing devils to offshore islands, including environmental impact assessment, and trial in appropriate locations if considered feasible (High);
f. Continue to develop, update and implement meta-population policies and guidelines e.g. biosecurity guidelines and risk categorisation, options for breeding facilities reaching capacity, options for managing DFTD or another disease in the Insurance Population (High); and
g. Develop protocols (disease and behaviour management, and logistics) to release devils back into their natural range, and trial these methods (High).

All tasks will be conducted in accordance with the Captive Management Plan (Lees 2005), Insurance Population Strategy (STTDP 2007b) and the Meta-population Framework (CBSG, DPIPWE and ARAZPA 2009). All tasks are high priority. This action will be ongoing for the life of the Recovery Plan, and will be conducted by DPIPWE, CBSG, ZAA, the CVO, and partnership organisations.

Action 2: Manage devil facial tumour disease in the wild

As explained in 'Strategy for Recovery', the options for wild disease management are limited. Tasks currently included (and their overall priority level) are:

a. Continue to implement and monitor disease suppression by culling diseased animals, and extend to other areas if applicable (High);
b. Assess the impact of large-scale fencing on devil movements and habitat use (High);
c. Investigate the feasibility (including ecological, logistic, financial and social impacts) of fencing large uninfected areas in time to prevent disease exposure, and implement if feasible (High); and
d. Using results of research, identify, trial and monitor other measures to suppress DFTD in the Tasmanian devil population (High).

These High priority tasks are being implemented by DPIPWE, and will be ongoing for the duration of the Recovery Plan.

Where appropriate and cost-effective, wild management will support other recovery actions, e.g. diseased devils and tissue samples from disease suppression will be used for disease investigations (Action 4), results from movement and fence assessments will be used to aid monitoring and free-living insurance population activities (Action 1).

Action 3: Monitor Tasmanian devils

Monitoring of Tasmanian devils includes disease monitoring. Tasks in this action are:

a. Deploy and monitor remote cameras at appropriate locations (High);
b. Undertake mark re-capture trapping surveys at appropriate timing and locations (High);
c. Develop other techniques to monitor the Tasmanian devil population and implement these at appropriate timing and locations (High); and
d. Analyse and interpret data regularly, and use results to evaluate and adjust strategies and actions (High).

The purposes of devil monitoring can be focused on:

- estimating changes in numbers of devils (total population estimate and in particular areas);
- maintaining knowledge of the disease front;
- informing disease modelling;
- determining whether devils are present in an area and whether there is local extinction;
- identifying any atypical responses to the disease; and
- investigating particular areas of interest.

Monitoring devils is a High priority, and will be ongoing for the duration of the plan. Representative sites across Tasmania will continue to be monitored, with additional sites if required. Monitoring will follow the principles outlined in the Wildlife Monitoring Strategy (DPIW 2008c).

In addition to data on devils, monitoring will include ad hoc recording of foxes and devil roadkill, and where possible counts of vertebrate species likely to show a response to a dearth of devils (e.g. raptors, forest ravens, quolls, and feral cats) to contribute to monitoring of other threats (Action 5). Where appropriate, samples will be collected for disease investigations (Action 4). This may include samples and/or animals of interest for use in vaccination or resistance trials. New disease diagnostic tools will be applied as soon as they are available.

Action 4: Conduct disease investigations

Tasks currently in this action, in priority order, include:

a. Develop and validate a pre-clinical diagnostic test for DFTD that can be used in the wild (High);
b. Investigate the nature of DFTD transmission and latency periods (High);
c. Investigate and map the strains of DFTD across Tasmania, using tumour samples (High);
d. Study the Tasmanian devil's immune system and response to DFTD, including vaccine feasibility, development and testing (High);
e. Investigate potentially resistant genomes and test breeding for resistance (High); and
f. Investigate and trial treatment options (Low).

Disease investigation tasks 4a–e. are a High priority, while f is a Low priority. Investigations will continue for the life of the Recovery Plan, though specific tasks may be completed or lead to different research directions. The relative priority of each research task is likely to change as research is conducted and results available, however, research that aids wild management will remain the highest priority. These tasks will be conducted by the disease investigating team, which includes DPIPWE, UTas, and a range of centres for disease research within Australia and overseas (see Appendix 1).

Action 5: Manage other threats in the wild

Foxes require management action immediately before they become established. Other threats include collisions with vehicles, habitat loss and illegal culling. This action includes:

a. Maintain the Fox Eradication Program, modified as per the program review (High);
b. Continue existing activities to measure and minimise the impact of threats other than DFTD, with additional monitoring if required (Medium);
c. Collate and analyse information on the impact of other threats — from task b, and Actions 3, 6 and 8 (Medium);
d. Collate technical information on protecting and managing key habitat elements e.g. dens, and provide to all Commonwealth, State and local agencies regulating development, native vegetation conversion and/or forestry operations (Low);
e. Conduct specific research into the extent of impact of other threats and effectiveness of mitigation methods as required (Low); and
f. Implement additional threat reduction in appropriate areas, if and when required (Low).

Fox eradication is a High priority. Continuing existing activities and analysing information on the impact of other threats are Medium priority tasks. The other tasks are Low priority.

If monitoring or other evidence indicates the relative level of threat to devils in a particular area (or over all of Tasmania) may have increased, additional monitoring and the priority of tasks 5e and/or 5f will be considered. Specific research may include identifying the threat/s and trial of mitigation methods. Examples of possible additional threat reduction activities under task 5f include: installations to reduce devil roadkill (traffic-calming devices, warning signs); control of feral cats; and additional issue-specific communication.

This action will be coordinated by DPIPWE, and implemented by DPIPWE and partnership organisations, on an ongoing basis for the duration of the Recovery Plan.

Action 6: Research and measure habitat variables

Investigating habitat variables is important in the long-term, but currently considered lower priority relative to disease-related actions. Tasks included in this action are:

a. Continue to investigate the ecosystem consequences of reduced Tasmanian devils (Low); and
b. Further define and map devil habitat requirements, including habitat critical to survival (Low).

Investigating ecosystem consequences will be conducted by DPIPWE, UTas and Uni Syd, and will continue for the life of the Recovery Plan. Further defining and mapping devil habitat requirements, including habitat critical to survival, will be conducted by DPIPWE. Where possible this action will be integrated with devil monitoring (Action 3).

Action 7: Coordinate recovery program

Given the complex and rapidly changing situation, recovery program coordination is a High priority. Tasks include:

a. Ensure appropriate oversight of expenditure on Recovery Plan actions (High);
b. Form a Recovery Team to regularly assess the effectiveness of the recovery program, and to review recovery tasks and priorities (High); and
c. Ensure technical advice, used in determining priorities and action details, is sought from all appropriate experts (High).

This action is ongoing for the life of the Recovery Plan. DPIPWE, the STTDP Steering Committee and the Recovery Team will conduct this activity, with additional expert advice e.g. AusVet, Conservation Breeding Specialist Group, as required.

Action 8: Communicate with community and stakeholders

Communication tasks include:

a. Develop and distribute stakeholder-targeted recovery program information, including a web page reporting any changes to the priorities or components of the program (Medium);
b. Continue to develop and distribute educational and awareness materials for schools, the Aboriginal community, stakeholder groups and the general public, including ways to reduce and report devil roadkill, illegal culling, and habitat destruction (Medium);
c. Promote and manage the volunteer program to facilitate community involvement (Medium);
d. Develop policy and procedures for information sharing and ownership, for research that contributes to, informs or supports the Recovery Plan (Medium); and
e. Implement a data management system to capture and manage information centrally and to provide for appropriate analysis (Medium).

Communication tasks are of Medium priority. They are currently coordinated by DPIPWE under the STTDP communication strategy (STTDP 2008a), and will be ongoing for the duration of the Recovery Plan.

3.5 Management practices

Management practices necessary to avoid significant impacts on Tasmanian devils include:

- compliance with existing protection under the TSP, EPBC and NC Acts;
- compliance with existing clearing and development restrictions and regulations;
- conservation management of all relevant National Parks, Nature Reserves and National and World Heritage areas;
- continue private land conservation schemes;
- retaining as much suitable habitat as possible;
- ongoing fox eradication activities under the Fox Eradication Program;
- ongoing management of existing captive Tasmanian devils, in accordance with the protocols and policies developed;
- maintain Tasmanian devil quarantine facilities;
- continue education activities e.g. motorist awareness and responsible cat ownership programs;
- continue development of guidelines and regulations for Tasmanian devils during fire and forestry management activities;
- ongoing implementation of wildlife roadkill mitigation e.g. traffic-calming devices, warning signs;
- implement wildlife-sensitive road design, such as taking into account landscape characteristics dangerous for devils (e.g. deep gutters and steep banks), and use of features to allow escape from the road (e.g. runways, pipes and ramps);
- provide corridors of suitable habitat in off-reserve areas.

Actions that result in any of the following within areas of habitat critical for survival may result in a significant impact on the Tasmanian devil:

- increase the spread of the disease (such as moving diseased animals into an area which is disease-free);
- the construction of new roads or substantial upgrades to existing roads;
- loss or intensified use of habitat, such as clearing for urban development, flooding associated with dam building, intensifying or changing of agricultural land use, more large-scale clear-felling and burning; and
- any activities leading to destruction of a cluster of maternal dens.

The EPBC Act Policy Statement for Tasmanian devils (DEH 2006) outlines the implications of listing as a nationally threatened species, including significant impact criteria.

3.6 Implementation

Implementation of recovery actions will be overseen and guided by a Recovery Team or similar group. Working groups with specialist focus, such as in insurance population management (e.g. Captive Management Group) will report to the Recovery Team on progress and success of implementation. The Recovery Team will evaluate progress against the recovery criteria at least once per year, and adjust the relative priorities and inclusion of recovery actions as necessary. While the Save the Tasmanian Devil Program is operating, the Recovery Team will advise the STTDP Steering Committee on the overall priorities and timing for recovery activities.

The recovery actions have not been costed due to:

- the many uncertainties on the treatment and impacts of the disease and resultant complex nature of the recovery program;
- the need for feasibility assessments to determine whether some tasks are implemented (e.g. offshore island releases); and
- the potential need for additional or expanded tasks depending on the results of research and outcomes of other actions.

The Steering Committee will determine the allocation of funds to, and management of, program components, and will annually review the Recovery Plan budget to ensure as many as possible recovery actions are implemented.

Recovery projects will be funded through various direct and indirect funding activities undertaken by the Australian Government, the Tasmanian Government, Australian Research Council grants, independent grants, industry organisations, conservation groups, and the Australian public, through efforts such as The Save the Tasmanian Devil Appeal.

A Recovery Plan should remain in place until stabilisation and maintenance of the Tasmanian devil population enables a change in conservation status to be considered. As required under the EPBC Act the plan will be reviewed within 5 years of adoption, and varied if necessary.

3.7 Benefits/impacts to biodiversity

Recovery and maintenance of Tasmanian devils will avoid many of the ecosystem impacts that may occur if the devils continue to decline.

In particular, recovery of the Tasmanian devil may prove significant in suppressing fox and feral cat numbers, and therefore reduce the risk of fox and cat predation on other small and medium mammals and ground nesting birds. Increases in cats and/or foxes mean an increased extinction threat to many mammals and ground nesting birds that have declined drastically in southern mainland Australia since fox and cat introductions, but which persist in Tasmania (Jones et al. 2007). These include the eastern quoll, Tasmanian bettong (*Bettongia gaimardi*), Tasmanian pademelon (*Thylogale billardierii*), eastern-barred bandicoot (*Perameles gunnii*), spotted-tailed quoll, and New Holland mouse (*Pseudomys novaehollandiae*). The flightless, endemic Tasmanian native-hen (*Gallinula mortierii*) is also likely to be at high risk. Many other small mammals and ground nesting birds endemic to Tasmania could potentially become threatened as a result of fox and/or cat predation.

Tasmanian devils are directly associated with an intestinal parasite, *Dasyurotaenia robusta,* listed as Rare under the TSP Act. This tapeworm is found only in devils. The aim to maintain wild devils, and the insurance population aim to maintain the suite of associated flora and fauna (e.g. parasites, gut bacteria), will both aid in maintaining this tapeworm species.

The introduction of Tasmanian devils to offshore islands could have impacts on the biodiversity of islands, in particular seabird colonies. Less direct impacts on island biodiversity are also possible. In determining whether any translocations can occur, the likelihood and extent of all potential impacts must be formally assessed.

3.8 Role and interest of Indigenous groups

In the preparation of this plan the important role Tasmanian Aboriginal people have played in land management was recognised, and the impact of European settlement on this role acknowledged.

The following Aboriginal organisations have been consulted on the significance of the Tasmanian devil in Aboriginal cultural tradition, and on their knowledge, role and interest in devil management: Aboriginal Land Council of Tasmania, Tasmanian Aboriginal Centre, and Tasmanian Aboriginal Land and Sea Council.

Tasmanian devils have been known to Indigenous Tasmanians by the names 'tardiba' (Robertson 2005) or 'purinina' (DPIPWE 2009b).

Implementation of this plan will involve:

- knowledge sharing;
- participation in education and training relevant to threatened species management; and
- engagement in recovery actions where relevant to aboriginal land management and communities.

The potential for some recovery actions to adversely impact on Aboriginal heritage has been recognised. For example:

- monitoring activities that include the construction of pitfall traps could damage middens; and
- the potential translocation of devils could impact on the taking of muttonbirds (shearwaters) on offshore islands.

To mitigate the risk of these impacts, Aboriginal Heritage Tasmania will be consulted prior to the design of recovery actions that may have the potential to impact on Aboriginal heritage. Aboriginal Heritage Tasmania, after going through its normal consultation and assessment process, will advise if an Aboriginal heritage investigation or mitigation measures are needed to protect Aboriginal heritage

If, during any recovery activity, suspected evidence of Aboriginal heritage significance is found, this will be reported to Aboriginal Heritage Tasmania, and the activity will be suspended at that location pending appropriate follow-up.

3.9 Affected interests

The stakeholders and other affected interests in the recovery program include:

<u>Australian Government</u>
Department of Agriculture, Fisheries and Forestry
Department of Defence
Department of Sustainability, Environment, Water, Population and Communities

<u>Tasmanian and local government</u>
All local councils
Department of Economic Development and Tourism
Department of Infrastructure, Energy and Resources (includes Forest Practices Authority)
Department of Primary Industries, Parks, Water and Environment (includes Parks and Wildlife Service)
Forestry Tasmania
Mineral Resources Tasmania

<u>Industry organisations and private companies</u>
Private Forests Tasmania

Gunns Ltd
Tasmanian Farmers and Graziers Association
Tourism Industry Council Tasmania

Non-government organisations
Against Animal Cruelty Tasmania
Australasian Raptor Association
Australian Veterinary Association
Australian Wildlife Conservancy
Birds Australia
Conservation Volunteers Australia
Environment Tasmania
Indigenous Groups
Landcare Groups
Royal Automobile Club of Tasmania
RSPCA
Save the Tasmanian Devil Program Stakeholder Reference Group
Tarkine National Coalition
Tasmanian Conservation Trust
Tasmanian Wilderness World Heritage Area Consultative Committee
University of Tasmania and other research bodies (see Appendix 1)
Vets and wildlife hospitals
Wildcare Incorporated (includes 'Friends of...' groups)
Wildlife Tourism Association of Australia
WWF-Australia
Zoological parks and wildlife parks
Zoos Australia Association (ZAA)

Natural Resource Management (NRM) regional bodies
Cradle Coast NRM
NRM North
NRM South

Other
Landowners
Independent wildlife biologists and conservationists

3.10 Social and economic impacts/benefits

Although Tasmanian devils occur throughout the Tasmanian mainland on lands of all tenures, it is not anticipated that implementation of this Recovery Plan is likely to cause significant adverse social and economic impacts. The Tasmanian devil has the highest level of legal protection as a listed threatened species at both the State and national level.

As the largest extant marsupial carnivore and a well known species, the Tasmanian devil attracts much national and international interest. Social and economic benefits of Tasmanian devil recovery include: maintaining tourism; avoiding the costs of ongoing fox control and loss of income from fox establishment; and devils retaining their ecosystem functions, such as maintaining bush and farm hygiene and reducing carcasses in the landscape. Maintaining Tasmanian devils in the wild will help preserve the heritage values of wild remote areas such as the Tasmanian Wilderness World Heritage Area and the Tarkine.

Introduction of Tasmanian devils to any islands, if this occurs, may have some positive and negative impacts on tourism. These will be considered during planning of any introductions, and any potential negative social and economic impacts must be minimised.

3.11 International obligations

The Tasmanian devil is not listed on any international wildlife agreements. However it is a World Heritage value of the Tasmanian Wilderness World Heritage Area (TWWHA) (DSEWPaC 2010b). Under the World Heritage Convention Australia has an obligation to identify, protect, conserve and transmit to future generations the outstanding universal value of world heritage places. At the same time care must be taken not to have unintended impacts on other values of the TWWHA in the process of managing the Tasmania devil.

The recovery plan is consistent with these obligations.

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APPENDIX 1 Organisations involved in research

Organisation involved in research on Tasmanian devils and Devil Facial Tumour Disease, and the topic they have or are researching, include.

Australian National University, Canberra — evolution of tumour chromosomes, molecular evolution in devils, genetic markers, maps of devil and tumour strains

Australian Museum, Sydney — Genetic diversity in Tasmanian devils

Benirova, Seattle USA — devil BAC library (a collection of DNA fragments that is stored and propagated in a population of micro-organisms, bacteria.

Broad Institute, Boston USA — genome sequences of marsupials

Children's Cancer Institute of Australia, Sydney — DNA sequencing

Cold Spring Harbour Laboratory, New York USA — DNA sequencing DFTD and devil genes

CSIRO, Adelaide — spatial modelling devil density and disease

CSIRO Land and Water, Canberra — GIS mapping of spatial and temporal distribution of the disease

CSIRO Livestock Industries Australian Animal Health Laboratory, Geelong — search for involvement of a virus, pre-clinical diagnostic test

DPIPWE Mt Pleasant, Launceston — defining the disease, body function healthy and diseased animal, monitoring of tumour samples, rate of tumour growth, identify and map different strains, method of transmission by cell transfer, immune response to tumour, validation of pre-tumour diagnostic test, laboratory support for collaborative research, role of telomeres in disease development and progression

DPIPWE, Hobart — the age prevalence of the disease, impact of the disease on population parameters, molecular evolution in devils, genetic markers

Imperial College, London — modelling tumour growth, latent period

IUCN Conservation Breeding Species Group, Minnesota USA — Population Health and Viability Assessment

James Cook University, Townsville — devil and thylacine genetics

Johns Hopkins, Baltimore Maryland USA — telomeres

Landcare New Zealand, Lincoln NZ — modelling disease dynamics

Macquarie University, Sydney — Genetic diversity in devils

Menzies Research Institute, Hobart — Immune response to tumour, identify tumour antigens, vaccine development, DNA sequencing DFTD and devil genes

Murdoch University, Perth — histology of tumour, origin of the cancer cells

Oregon State University, Oregon USA — genetics and dispersal in relation to landscape features

Penn State University, Pennsylvania USA— DNA sequencing DFTD and devil genes

Roche Diagnostics, New York USA — DNA sequencing DFTD and devil genes

Sanger Institute, Cambridge UK — molecular evolution in devils, genetic markers, DNA sequencing DFTD

University of Adelaide, Adelaide — molecular evolution in devils, genetic markers

University of New South Wales, Sydney — gene sequencing project

University of Queensland, Brisbane — population, demographic and genetic impacts, devil dispersal patterns

University of Sydney, Sydney — genome sequences of marsupials, immune response to tumour, MHC antibodies, molecular evolution in devils, genetic markers

University of Tasmania, Hobart — Genetic diversity, ecology and biology of devils, modelling disease spread and effect, force of infection, pre-tumour diagnostic test using blood component separation, interactions between devils, changes in diseased populations, origin of tumour cells, molecular evolution in devils, genetic markers, ecosystem impacts of devil decline, immunology and vaccine development, habitat occupancy in relation to forestry and farming, modelling tumour growth, latent period, modelling devil movements

University of Utrecht, Utrecht the Netherlands — modelling devil movements

Washington State University, Washington USA — genetics and dispersal in relation to landscape features

The Walter and Eliza Hall Institute of Medical Research, Melbourne — tumour transcriptome, spleen transcriptome

Zoos SA, Adelaide — molecular evolution in devils

For a full list of technical publications see www.tassiedevil.com.au