Department of Sustainability and Environment

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National Recovery Plan for the Spotted-tailed Quoll *Dasyurus maculatus*

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Australian Government

Victoria The Place To Be

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This Recovery Plan has been developed with the involvement and cooperation of a range of stakeholders, but individual stakeholders have not necessarily committed to undertaking specific actions. The attainment of objectives and the provision of funds may be subject to budgetary and other constraints affecting the parties involved. Proposed actions may be subject to modification over the life of the plan due to changes in knowledge.

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Cover photograph: Spotted-tailed Quoll *Dasyurus maculatus* by Jenny Nelson.

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Summary

The Spotted-tailed Quoll *Dasyurus maculatus* is a distinctive marsupial carnivore endemic to eastern Australia, where it is widely distributed from north-eastern Queensland to Tasmania. Two subspecies are currently recognised: *D. maculatus gracilis*, restricted to north-eastern Queensland; and *D. maculatus maculatus*, that occurs from southern Queensland through to south-western Victoria and Tasmania. The species has suffered a substantial decline in range and abundance since European settlement of Australia. *Dasyurus m. gracilis* and *D. m. maculatus* (southeastern mainland population) are listed as Endangered under the *Environment Protection and Biodiversity Conservation Act* 1999, and *D. m. maculatus* (Tasmanian population) is listed as Vulnerable under this Act. Major threats to the Spotted-tailed Quoll are thought to include habitat loss, modification and fragmentation, timber harvesting, poison baiting, competition and predation from introduced carnivores, deliberate killing, road mortality, wildfire and prescribed burning, poisoning by Cane Toads and climate change. This national Recovery Plan for the Spotted-tailed Quoll is the first national recovery plan prepared for the species. The Plan details the species' distribution, habitat, conservation status, threats, and recovery objectives and actions necessary to ensure the long-term survival of the Spotted-tailed Quoll. It is intended that local plans and actions for recovery will conform to this national plan.

Species Information

Description

The Spotted-tailed Quoll *Dasyurus maculatus* is one of Australia's largest extant marsupial carnivores (Edgar & Belcher 1995). The striking pelage is sandy to rufous or dark brown with irregular white spots covering the animal's back, sides and extending down the tail, and its stomach is cream to white (Belcher 2000). The large size and prominently spotted tail distinguish the Spotted-tailed Quoll from other quoll species (Edgar & Belcher 1995; Burnett *et al*. in press). Males can grow to 1.3 m in length (including tail) and weigh up to 7 kg (av. 2.6–4.6 kg), while females are smaller, to about 85 cm in length and 4 kg in weight (av. 1.5–2.2 kg) (Green & Scarborough 1990; Watt 1993; Jones 1997; Belcher 2003; Andrew 2005). The northern subspecies is considerably smaller than the southern subspecies, with an average male weight of 1.6 kg and female weight of 1.1 kg (Burnett 2001).

Two subspecies of the Spotted-tailed Quoll are currently recognised: *Dasyurus maculatus gracilis* from north-eastern Queensland; and *Dasyurus maculatus maculatus* from south-eastern Australia, including Tasmania. Genetic analysis indicates that the Tasmanian populations are sufficiently distinct from the mainland populations of *D. m. maculatus* to warrant subspecific status (Firestone *et al*. 1999). Since the Tasmanian subspecies has not yet received formal published taxonomic recognition, the two southern subspecies will be referred to as *D. m. maculatus* (south-eastern mainland population), and *D. m. maculatus* (Tasmanian population). In the text general references to the 'Spotted-tailed Quoll' refers to all subspecies, unless specified otherwise.

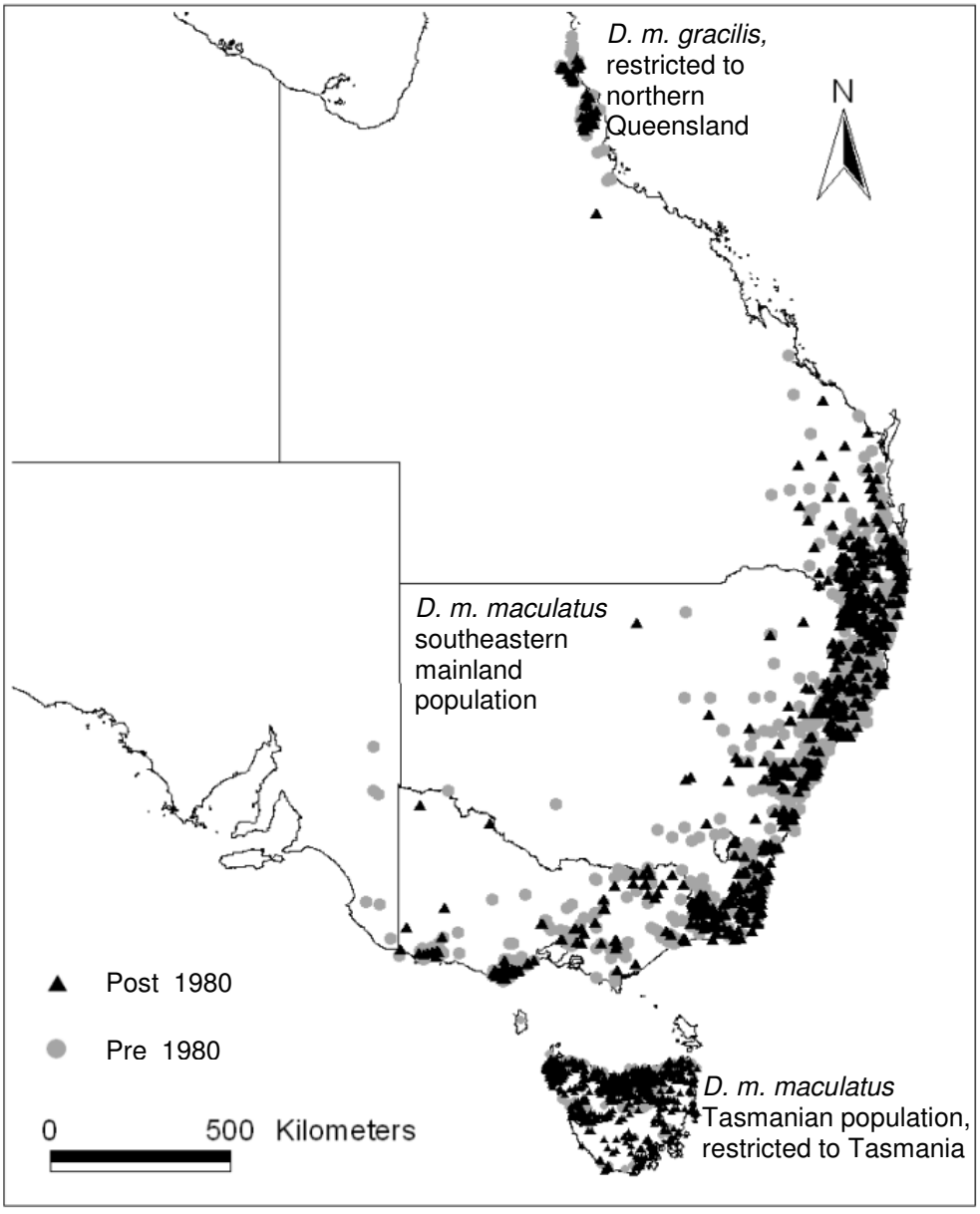
The average lifespan of Spotted-tailed Quolls is relatively short, with estimates of three years for animals in northern Queensland and northern New South Wales (Burnett 2001; Jones *et al.* 2003; Körtner *et al.* 2004; Andrew 2005), and five years in southern New South Wales and Victoria (Belcher 2003). In captivity, female quolls can reach six years of age (Andrew 2005). Sexual maturity is reached at about 11–12 months of age in the wild and in captivity (Fleay 1948; Edgar & Belcher 1995; Burnett 2001; Andrew 2005), although some females do not produce a litter until their second year (Burnett 2001; Belcher 2003; Nelson 2007). Although breeding may not always occur in successive years, most females produce a litter annually (Burnett 2001; Belcher 2003; Andrew 2005; Nelson 2007). The average litter size is five young (Settle 1978; Edgar & Belcher 1995; Burnett 2001), with litter size apparently increasing with female age, in both wild and captive animals (Andrew 2005). There is some evidence of high mortality during the period from birth until weaning (Fleay 1948; Belcher 2003), although high annual recruitment of sub-adults into study populations has also been recorded (Burnett 2001; Körtner *et al.* 2004).

The Spotted-tailed Quoll typically occurs at low densities, as adults are solitary and occupy large home ranges. Female home ranges are generally non-overlapping and 88–1515 ha in size (Belcher & Darrant 2004; Andrew 2005; Claridge *et al.* 2005; Glen & Dickman 2006a; Nelson 2007). Male home ranges are much larger, from 359–5512 ha in size, and overlap and encompass multiple female home ranges (Belcher & Darrant 2004; Andrew 2005; Claridge *et al.* 2005; Glen & Dickman 2006a). The species is capable of covering large distances in a short period of time, with animals recorded moving at least 8 km in a day and 19 km in a week (Andrew 2005).

The species is carnivorous, hunting on the ground and in trees (Settle 1978; Jones & Rose 1996; Jones & Barmuta 2000; Burnett 2001), feeding on a wide variety of prey including mammals, birds, reptiles and invertebrates (including carcasses) although mammals, particularly medium-sized mammals, constitute the bulk of the diet (Belcher 1995, 2000; Jones & Barmuta 1998; Burnett 2001; Andrew 2005; Glen & Dickman 2006b; Belcher *et al.* 2007; Dawson *et al.* 2007; Jarman *et al.* 2007). The relative proportions of dietary components varies between the sexes and age-classes (Belcher 1994, 1995; Jones & Barmuta 1998) as well as seasonally, annually, between sites, and in accordance with prey availability (Belcher 1995; Andrew 2005; Glen & Dickman 2006b; Belcher *et al.* 2007).

Distribution

Figure 1. Distribution of the Spotted-tailed Quoll



The Spotted-tailed Quoll is widely but patchily distributed in eastern Australia, occurring from north-eastern Queensland to Tasmania, although is apparently absent from central Queensland (Figure 1). The northern subspecies is now thought to be confined to two extant populations; one centred on the Windsor and Carbine Tablelands, Thornton Peak, Mount Finnegan and associated smaller ranges, and the other centred on the Atherton Tablelands and associated mountain ranges (Burnett 2001). The mainland population of *D. m. maculatus* occurs from near Gladstone in south-eastern Queensland, through New South Wales to western Victoria (Mansergh 1984; Edgar & Belcher 1995; Maxwell *et al.* 1996), but is now presumed to be extinct in South Australia (Edgar & Belcher 1995). In Tasmania the species occurs widely across the state, but no longer occurs on King Island and Flinders Island (Jones & Rose 1996).

Habitat

The Spotted-tailed Quoll is a primarily forest-dependent species that occupies a wide range of habitat types, although all appear to be characterised by relatively high (> 600 mm/yr) and predictable seasonal rainfall. The northern subspecies, *D. m. gracilis*, is confined to the relatively cool, wet and climatically equable upland closed-forests (mostly above 900 m altitude) that occur in the upper catchments of rivers draining east and west of the Eastern Escarpment in the Wet Tropics bioregion of north-eastern Queensland (Burnett 2001). Vegetation types typical of this habitat are simple and complex notophyll vine forest, simple microphyll vine-fern forest and simple microphyll vine-fern thicket.

The southern subspecies, *D. m. maculatus*, has been recorded from a wide range of habitat types including rainforest, wet and dry sclerophyll forest, coastal heathland, scrub and dunes, woodland, heathy woodland, swamp forest, mangroves, on beaches and sometimes in grassland or pastoral areas adjacent to forested areas (Green & Scarborough 1990; Belcher 2000; Jones & Barmuta 2000; Andrew 2005). Relatively high densities of the species have been recorded from both wet and dry forest habitats (Watt 1993; Mansergh 1995; Jones & Rose 1996; Belcher 2000; Dawson 2005; Glen & Dickman 2006b).

The Spotted-tailed Quoll occupies home ranges of several hundred to several thousand hectares in size. Spotted-tailed Quolls use multiple dens (possibly in excess of 20) and usually move between them every 1–4 days (Belcher 2000; Burnett 2001; Körtner *et al.* 2004; Andrew 2005; Belcher & Darrant 2006a; Glen & Dickman 2006a). Recorded den sites include rock crevices, hollow logs, hollow tree buttresses, tree hollows, windrows, clumps of vegetation, caves and boulder tumbles, under buildings and underground burrows, including those of rabbits and wombats (Watt 1993; Belcher 2000; Burnett 2001; Körtner *et al.* 2004; Andrew 2005; Belcher & Darrant 2006a; Glen & Dickman 2006a; M. Jones pers. comm.). Maternal den sites include rock crevices, caves, boulder tumbles, hollow logs, hollow tree roots and burrows (Belcher 2000; Burnett 2001; Andrew 2005; Belcher & Darrant 2006a; Glen & Dickman 2006a; Nelson 2007). Female quolls will dig burrows when a suitable substrate is available (Andrew 2005).

A study of the landscape components of habitat used by Spotted-tailed Quolls at two sites in south-eastern Australia found that the preferential use of particular landscape components (e.g. gullies and escarpments) was related to prey densities and den availability (Belcher 2000; Belcher & Darrant 2006b). While habitat-use at other sites will most likely be driven by the same factors identified by these studies, given the broad range of habitat types occupied by Spotted-tailed Quolls throughout their geographic distribution, habitat-use in other areas may correspond to different landscape and habitat features (Belcher 2000; Belcher & Darrant 2006b). This premise is reflected by the species' core distribution in Tasmania, which corresponds with areas of high productivity governed by predictable seasonal rainfall and relatively warm mean annual temperatures (Jones & Rose 1996).

Habitat that is critical to the survival of the Spotted-tailed Quoll includes large patches of forest with adequate denning resources and relatively high densities of medium-sized mammalian prey (Belcher 2000; Belcher & Darrant 2006b; Glen & Dickman 2006a, b). However, the threshold densities of these critical components required to support quoll populations are unknown. Consequently it is currently not possible to define (or map) habitat critical to the survival of the Spotted-tailed Quoll. An action proposed in this Recovery Plan is to determine measures of habitat quality and to identifiy and map high quality habitat throughout the species' range (Action 2.4). Given the threatened status of the Spotted-tailed Quoll, all habitats within its

current distribution (Figure 1) that are known to be occupied are considered important. There is currently insufficient information to identify potential habitat that the species may recolonise or to which it could be reintroduced.

Important Populations

Table 1. Important populations of Spotted-tailed Quolls

State	Population	Basis for 'importance' classification
Dasyurus maculatus maculatus Tasmanian population		
TAS	Freycinet National Park	research population
	Central-north Tasmania (including Great Western Tiers to Narawntapu)	stronghold & research population
	Cradle Mountain National Park	stronghold & research population
	Far northwestern Tasmania (including the Smithton and Marrawah regions)	stronghold & research population
	Eastern Tiers/northern Midlands (including Nugent and Ross regions)	stronghold population
	Southern forests/South Coast (including the Hastings region)	stronghold population
	Gordon River system	stronghold population
	South-west Cape	stronghold population
Dasyurus maculatus maculatus south-eastern mainland population		
VIC	Great Otway National Park	loss would cause range contraction
	Mt Eccles National Park	loss would cause range contraction
	East Gippsland (including Errinundra Plateau and Upper Snowy River Catchment)	stronghold & research population
NSW	Marylands National Park and adjacent freehold property 'Mowamba'	stronghold & research population
	Limeburner's Creek Nature Reserve	research population
	Northern Tablelands (from Barrington Tops to the Glenn Innes region)	stronghold & research population
	Greater Blue Mountains	loss would cause range contraction
	Tallaganda State Forest	research population
	Badga State Forest	research population
	Kosciuszko National Park	stronghold & research population
Sth QLD	Stanthorpe to Wallangarra, Granite Belt/New England Tablelands	stronghold & research population
	Cherrabah Homestead (between Warwick and Killarney)	stronghold & research population
	Main Range-McPherson Range west	stronghold population
	Lamington Plateau-McPherson Range east	stronghold population
	Burnett Range	loss would cause range contraction
	Dalby region	loss would cause range contraction
Dasyurus maculatus gracilis		
Nth QLD	Daintree region	stronghold & research population loss would cause range contraction
	Atherton region	stronghold & research population
	Great Basalt Wall	loss would cause range contraction
	Mt Spec region	loss would cause range contraction

These are defined as populations (defined by geographic area) considered to be of particular importance to the long-term survival of the Spotted-tailed Quoll, based on current knowledge.

Given the threatened status of the Spotted-tailed Quoll throughout its range, all populations are considered to be important. The Endangered status of the two mainland subspecies further elevates the level of importance of these populations. Populations may be classified as being of core importance to the long-term survival and recovery of the species if they are:

- 'stronghold' populations within a region (i.e. areas of high abundance);
- populations that are known to be genetically disparate;
- populations that, if lost, would cause a significant contraction in the species' range, and
- populations that have been the focus of long-term research and hence have good base-line data that will increase the understanding of the species' ecology.

Except for intensively trapped research sites, limited information exists on the distribution and abundance of the species throughout much of its range, particularly in regions with extensive tracts of contiguous habitat. The genetic diversity within and between populations and the location of barriers to movement are also largely unknown, meaning the definition of discrete, functional populations is not always possible (this is less problematic in areas that contain populations that are isolated as a result of habitat fragmentation). Some researchers and land managers are therefore hesitant to highlight 'important' populations based on this incomplete information. Consequently, it is acknowledged that, as further survey and research work is conducted and our understanding of the species distribution is clarified, the list of important populations (Table 1) will be modified accordingly. In this table, a 'population' is defined purely as the Spotted-tailed Quolls occurring within a defined geographic area – there is no implication that these areas represent the bounds of functional populations.

Decline and Threats

The Spotted-tailed Quoll has declined in distribution and abundance throughout its total range, and many populations are now fragmented and isolated. The extent of total reduction in the species' range is unknown, although it may be as high as 50% (Maxwell *et al.* 1996). Historically, *D. m. gracilis* occurred from the Paluma Range near Townsville north to near Cooktown, in north-eastern Queensland. The southern most population in the Paluma Range (Mt Spec region) is possibly extinct, with no records since the early 1940s, despite high levels of visitation and human occupancy of that region. There are no recent records from the Big Tableland and Evelyn Tableland (although this may be due to the lack of recent targeted surveys). The northern taxon is now thought to be confined to two extant populations; one centred on the Windsor and Carbine Tablelands, Thornton Peak, Mount Finnegan and associated smaller ranges, and the other centred on the Atherton Tablelands and associated mountain ranges (Burnett 2001).

Dasyurus m. maculatus (southeastern mainland population) was formerly widely distributed on both sides of the Great Dividing Range, from near Gladstone in southern Queensland, through New South Wales, Victoria and extending into the south-east of South Australia (Mansergh 1984; Edgar & Belcher 1995; Maxwell *et al.* 1996). In southern Queensland, the subspecies is almost certainly extinct from the D'Aguilar Range west of Brisbane and from coastal districts from Coolangatta to Bundaberg (S. Burnett pers. comm.), and the remaining distribution and abundance are poorly known.

In New South Wales, the Spotted-tailed Quoll remains widely distributed within large areas of contiguous forested land, from the Queensland border to the Victorian border, although the species is thought to have declined by 25–50% since European settlement (Lunney *et al.* 2000).

At the time of European settlement the Spotted-tailed Quoll was thought to occur across 60% of Victoria, corresponding with the distribution of forests dominated by medium to tall eucalypts and centred around the Great Dividing Range. The present range of the species in Victoria is believed to have halved, and is now highly disjunct (Mansergh 1984). It is believed to be extinct from Wilson's Promontory, with the last record in 1960. Populations in and around Mount Eccles and the Otway Ranges in south-western Victoria, and the Macedon Ranges north-west

of Melbourne, are now isolated from the forests of the Great Dividing Range due to extensive clearing (Mansergh 1984). The Spotted-tailed Quoll is now presumed to be extinct in South Australia (Edgar & Belcher 1995).

Dasyurus m. maculatus (Tasmanian population) historically occurred on King Island and Flinders Island in Bass Strait (Hope 1972) but is now believed extinct there (Jones & Rose 1996). On mainland Tasmania the Spotted-tailed Quoll occurs across the State. The relatively high annual rate of habitat loss from the species' core range there as a result of the conversion of forest to agricultural land and plantations would suggest that the population is declining, although this has not been quantified (Anon 2001).

Aspects of the biology and ecology of Spotted-tailed Quolls render them especially susceptible to threatening processes. They are generally solitary and occupy large home ranges, and consequently occur at low population densities. They have a relatively short lifespan and a low overall reproductive output, with some females breeding only once or twice during their lives. Juvenile dispersal is male-biased and natal female philopatry occurs (Firestone *et al.* 1999; Belcher 2003; Andrew 2005), factors that may limit the ability of the species to recolonise fragmented patches of habitat. Consequently, Spotted-tailed Quoll populations are limited to large, relatively intact patches of forest and are significantly prone to threatening processes that reduce, degrade and fragment such habitat. Many of the prey of the Spotted-tailed Quoll are reliant on hollows for shelter and breeding and hence their abundance will be influenced by forestry practices that reduce these resources. This may also impact on the availability of den sites by reducing or limiting the abundance of hollow logs, especially in areas where rock den sites are rare or absent. The distribution and abundance of suitable prey are thought to be factors that strongly influence the distribution and abundance of breeding female Spotted-tailed Quolls, and hence populations of the species. In many parts of its range Spotted-tailed Quoll habitat is also occupied by introduced carnivores, and competition with and possibly predation by these species may limit quoll populations. In addition, quolls are known to be susceptible to poison baiting programs to control these introduced carnivores. Predation by Spotted-tailed Quolls on domestic poultry and scavenging of road-killed carcasses exposes the species to human persecution and road trauma.

The major threatening processes are discussed further below:

Habitat loss and modification

Habitat loss and modification is probably the greatest threat to Spotted-tailed Quolls (Mansergh 1984; Watt 1993; Jones *et al.* 2003; Belcher 2004; Burnett & Marsh 2004). For example, in south-east Queensland over 70% of the habitat within the species' former range has been cleared, most within the last 20 years (Maxwell *et al.* 1996). Similarly, Victoria's coverage of forests and dense woodlands has reduced from 74% prior to European settlement to 33% (Kile *et al.* 1980, cited in Mansergh 1984). It is estimated that 50% of the habitat from the species' core distribution in Tasmania has been cleared, with approximately half of the remaining habitat having been subjected to logging practices in the last 20 years (Jones & Rose 1996). This is particularly pronounced in northern and northwestern Tasmania where logging and the conversion of forest habitat to eucalypt and pine plantations has been occurring at an accelerated rate over the past 10–15 years (Kirkpatrick & Jenkin 1995). The relatively high rate of habitat loss would suggest that the population is declining, although this has not been quantified (Anon 2001). Coastal areas of northern New South Wales are under major pressure from spreading urban development, posing a significant threat to the important quoll populations there (Andrew 2005). While Spotted-tailed Quolls are sometimes observed in cleared farmland, these are presumably occasional forays made from adjacent forested areas in search of food (Jones & Rose 1996). The absence of the northern subspecies from the approximately 80,000 ha of cleared habitat on the Atherton and Evelyn Tablelands is also certain given the high intensity of human occupancy there, and lack of any records since the 1940s (Burnett 2001).

Fragmentation

The fragmented nature of much of the remaining habitat available to be used by Spotted-tailed Quolls has isolated many populations (Mansergh 1984; Watt 1993). Due to the naturally low population densities at which the species occurs, fragmented populations are often small in size and hence vulnerable to stochastic events and deleterious genetic effects (Watt 1993; Backhouse 2003; Firestone 2003). Habitat fragmentation also typically increases the exposure of individuals to other threats including road mortality, predation by domestic dogs, predation

and/or competition with other introduced predators, and persecution by humans (Burnett 1993; Watt 1993; Jones *et al.* 2003).

Timber harvesting

Timber harvesting occurs through a considerable proportion of the range of the Spotted-tailed Quoll (Mansergh 1984; Jones & Rose 1996) and has been implicated in localised population declines and extinctions (Mansergh 1984). However, a number of apparently healthy quoll populations continue to exist in some commercially (selectively) logged forests (Belcher 2000; A. Glen pers. comm.), indicating that the species exhibits a level of tolerance to some habitat disturbance. The northern subspecies still occupies areas that have undergone intensive selective logging, but only in areas that have not been subjected to extensive clearing and settlement (Burnett 1993). In southern New South Wales and eastern Victoria, Spotted-tailed Quolls were found to avoid forest patches 0–5 years after selective logging (40–60% canopy cover retained). However, selectively logged forest that, after 16–20 years, had a regenerated shrub layer and an abundance of defective saw logs to act as potential den sites, was preferentially used relative to its availability (Belcher 2000; Belcher & Darrant 2006b). Conversely, there is some indication that even-aged regrowth forests do not support quoll populations for 20–50 years after clear-fell logging (Belcher 2004). It is suggested that forestry practices (including controlled burns) that remove or reduce prey or critical habitat elements such as trees with hollows, hollow logs, a complex vegetation structure, >50% canopy cover and rock or burrow den sites, may render the habitat unsuitable, at least temporarily (Watt 1993; Belcher 2000; Glen & Dickman 2006a). In areas where rock den sites are not abundant, hollow logs and tree hollows are the preferred den sites. Given the very long time periods required to form hollows in trees and logs, intensive forestry practices could have a major impact on the availability of den sites, especially where logging is followed by burning (Andrew 2005). These practices may be particularly detrimental to a population if they coincide with the breeding season (Watt 1993). In Tasmania, only male Spotted-tailed Quolls and several non-breeding females were located in recently logged forest (C. Hawkins pers. comm.), highlighting the need to ensure that silvicultural systems are managed to maintain sufficient habitat to sustain breeding populations. A recent spatially explicit Population Viability Analysis modelling exercise predicted major population declines and a risk of extinction for Spotted-tailed Quolls in north-east Tasmania based on a range of projected logging regimes and the conversion of forest to plantation (M. Jones pers. comm.). This further highlights the need for adequate habitat reservation and management. Many of the arboreal mammalian prey of quolls are reliant on tree hollows for shelter and breeding and hence the abundance of these prey will be influenced by forestry practices (Gibbons & Lindenmayer 2002). Logging and fire events will also alter the abundance of some other potential prey species (Fox & McKay 1981; Lunney *et al.* 1987; Thompson *et al.* 1989).

Poison baiting

Poison baiting using 1080 occurs extensively throughout the range of the Spotted-tailed Quoll, primarily to control populations of Red Fox *Vulpes vulpes*, wild dogs *Canis lupus familiaris* and *Canis lupus dingo*, and European Rabbit *Oryctolagus cuniculus*, which are considerably more susceptible to 1080 than Spotted-tailed Quolls (McIlroy 1981, 1982, 1986). Laboratory measurements of the sensitivity of Spotted-tailed Quolls to 1080 indicate that the median lethal dose per individual that will kill 50% of a population (LD_{50}) is 1.85 mg kg^{-1} body weight (McIlroy 1981). The quantity of 1080 within baits varies depending on the target species. Most fox and dog baits contain 3 mg and 6 mg of 1080 respectively, although dog baits in Victoria typically contain 4.5 mg (R. Williamson pers. comm.). Based on the amounts of 1080 that represent an LD_{50} to different individual quolls, consumption of a single 3 mg bait would potentially kill juvenile and adult quolls that weigh less than 1.2 kg (Green & Scarborough 1990; Watt 1993; Jones 1997; Belcher 2000), whereas multiple 3 mg baits would need to be consumed to kill larger adults. Single baits containing a higher dosage of 1080 will kill larger individuals. A single 250 g dog bait containing 6 mg of 1080 is capable of killing all quolls weighing 2.3 kg or less which, based on the average weights of males and females, would equate to a large proportion of *D. m. maculatus* individuals and all *D. m. gracilis* individuals.

The removal of multiple non-toxic baits by an individual quoll has been shown to occur from bait stations spaced at 400 to 600 m apart (Glen & Dickman 2003a). Given the extensive movements of Spotted-tailed Quolls (Burnett 2001; Belcher & Darrant 2004; Andrew 2005; Körtner *et al*. 2004; Claridge *et al*. 2005; Glen & Dickman 2006a), the removal of multiple baits

is also a possibility from more widely-spaced bait stations, so even large individuals are at risk of 1080 poisoning from consuming multiple low-dose baits. High-dose dog baits are typically large portions of meat of approximately 250 g. Spotted-tailed Quolls are capable of consuming a large amount of food in a single meal, at least 700 g (Belcher 1998, 2000; Andrew 2005), which indicates they are capable of easily consuming at least two large baits. There is no published information on the long-term health, survival or fecundity of Spotted-tailed Quolls that ingest sub-lethal doses of 1080.

Captive and field trials have shown Spotted-tailed Quolls will consume non-poisoned Foxoff® baits as well as fresh and dried meat baits (Belcher 1998; Murray 1998; Murray *et al.* 2000; Burnett & Van Barneveld unpublished data). After a simulated aerial baiting trial using non-toxic air-dried fresh meat baits containing a biomarker, 12 of 18 captured quolls were found to have consumed baits (Belcher 2000; Murray & Poore 2004). A similar study conducted in different habitat in which non-toxic baits were either placed on the ground or aerially deployed by helicopter found that 6 of 10 and 8 of 17 quolls, respectively, had consumed baits (Claridge *et al.* 2006). In Victoria and Tasmania, meat baits are required to be buried to a depth of 8–10 cm and 10 cm respectively, to minimise take by non-target native species (Bloomfield 2001). This practice is also recommended in Queensland and New South Wales in areas where non-target poisoning is considered a risk (NSW NPWS 2001; DNRM 2003). Captive and field trials have shown that quolls will dig up and consume non-poisoned baits buried up to 10 cm (Belcher 1998; Glen & Dickman 2003a), but rarely baits buried deeper than this (Belcher 1998; Murray 1998). Constructing bait stations by mounding the substrate over the baits rather than burying them below the existing substrate to the same depth has been found to increase bait take by Spotted-tailed Quolls (Glen & Dickman 2003b). Given that foxes are known to cache baits, usually just below the soil surface (Saunders *et al.* 1999; Thomson & Kok 2002), quolls may also locate and consume these. The extensive daily (up to 8 km) and weekly (up to 20 km) movements of quolls mean they could potentially encounter a large number of baits (Andrew 2005).

The apparent sensitivity of Spotted-tailed Quolls to 1080, their wide-ranging behaviour, willingness to eat baits typically used in control operations, together with the results of trials using dyed non-toxic baits, clearly indicate that for control operations in which 1080 baits are not buried, a large proportion of individual Spotted-tailed Quolls in a population may locate and consume baits and die as a direct result. However, recent studies that assessed the immediate impact of baiting operations for foxes and wild dogs on Spotted-tailed Quoll populations in which 1080 baits were deployed on the surface of the ground, reported very few quoll deaths that could be attributed to 1080 poisoning (Körtner *et al.* 2003, Körtner & Watson 2005; NRW 2006; Claridge & Mills 2007; Körtner 2007). This is despite evidence that a comparatively high number of quolls monitored during three of the trials had eaten baits (Körtner & Watson 2005; Claridge & Mills 2007; Körtner 2007). Possible reasons for the small number of deaths include: lack of bait palatability (Körtner *et al.* 2003), low bait uptake or failure to encounter baits (Körtner & Watson 2005, Claridge & Mills 2007; DPF&I 2008), innate bait avoidance in populations exposed to regular baiting (Körtner & Watson 2005), partial consumption of baits and regurgitation or vomiting the bait before absorbing a lethal amount of 1080 (Körtner & Watson 2005; Claridge & Mills 2007, Körtner 2007). In the three trials in which quolls were known to have eaten baits and survived, measurements of the deterioration rate of 1080 in the baits over time indicated that, on the day of deployment, the amount of 1080 measured in the baits was substantially lower than the nominal 6 mg of 1080 intended (Körtner & Watson 2005; Claridge & Mills 2007; Körtner 2007). Rapid loss of toxicity post-deployment due to seepage, leaching by dew or rainfall and defluorination by microorganisms (McIlroy *et al.* 1988; Fleming & Parker 1991) would have resulted in baits quickly becoming non-lethal to quolls which may have accounted for the survival of at least some individuals known to have eaten baits during the trials (Körtner & Watson 2005; Claridge & Mills 2007; Körtner 2007).

Overall, the results of studies on the impact of 1080 baiting on Spotted-tailed Quoll populations (Körtner *et al.* 2003, Körtner & Watson 2005; NRW 2006; Claridge & Mills 2007; Körtner 2007) indicate that under field conditions quolls are probably not as susceptible to fatal poisoning as laboratory measurements of their sensitivity to 1080 (McIlroy 1981) and trials using non-toxic baits suggest (Belcher 2000; Murray & Poore 2004; Claridge *et al.* 2006). This is supported by the persistence of apparently robust populations of Spotted-tailed Quolls in areas with a history of regular aerial and/or ground baiting (Fleming 1996; Körtner *et al.* 2003; Körtner & Watson 2005; M. Oakwood pers. comm.). However, it is also clear that some individual quolls are

poisoned during control operations (Belcher 2003; NRW 2006; Körtner & Watson 2005). While the loss of a small number of individuals resulting from 1080 poisoning may have no population-level impact in areas where quoll populations are relatively large, in small, fragmented or declining populations, even small elevated mortality rates may markedly affect population viability (Körtner & Watson 2005; Todd *et al.* 2007). Other factors such as the history, seasonal timing, frequency or intensity of baiting, or the type of bait used, may also alter the susceptibility of populations, although these factors remain largely untested (Körtner *et al.* 2003, Körtner & Watson 2005; Claridge & Mills 2007). The relative success of different baiting regimes at reducing populations of feral predators is also unresolved. For example, there is evidence that a large number of surface-laid baits are taken by birds, limiting their exposure to exotic predators and potentially increasing the exposure of non-target species (Allen *et al.* 1989).

Continued research is required to clarify the impact of 1080 baiting on Spotted-tailed Quoll populations. In particular, questions remain regarding:

- the effect of sub-lethal doses of 1080 on fecundity and survival,
- whether the impact of baiting on Spotted-tailed Quoll populations is affected by the seasonal timing of baiting, the frequency and intensity of baiting, or the size and degree of isolation of quoll populations,
- the ability of Spotted-tailed Quolls to detect 1080 in baits and the development of bait aversion behaviour,
- the differential palatability of bait types,
- the proportion of baits that are cached during mound baiting programs and that are located and consumed by Spotted-tailed Quolls, and
- the susceptibility of Spotted-tailed Quolls to secondary poisoning.

Widespread strychnine baiting for dingoes has also been implicated in declines of the Spotted-tailed Quoll in New South Wales and historically of Eastern Quoll *Dasyurus viverrinus* and Tasmanian Devil *Sarcophilus harrisii* populations in Tasmania (Maxwell *et al.* 1996; Jones *et al.* 2003). Strychnine is considered to be a threat to Spotted-tailed Quolls in Queensland, where it is known to have caused deaths in the northern subspecies of Spotted-tailed Quoll (Burnett & Marsh 2004). The use of strychnine is still permitted in Queensland, New South Wales and South Australia (Fleming *et al.* 2001).

Competition and predation from introduced carnivores

There is speculation that competitive and/or predatory interactions are occurring between Spotted-tailed Quolls and the feral Cat *Felis catus*, foxes, and wild and domestic dogs *Canis lupus familiaris*, and that this may be suppressing quoll populations (Taylor 1986; Watt 1993; Belcher 1994; Maxwell *et al.* 1996; Burnett 2001; Jones *et al.* 2003; Glen & Dickman 2005, 2008). Incidences of Spotted-tailed Quolls being killed by dogs (Fleay 1932; Green & Scarborough 1990; Jones *et al.* 2003; Andrew 2005; Körtner *et al.* 2003; Körtner & Watson 2005; Körtner 2007), cats (Museum of Victoria record) and (possibly) foxes (Körtner *et al.* 2003) have been reported, but there is little information to determine frequency of interactions or impact on quoll populations.

Given the dietary and habitat overlap between the Spotted-tailed Quoll and introduced carnivores (Taylor 1986; Belcher 1994; Dickman 1996; Burnett 2001; Glen and Dickman 2008), competitive effects are also presumably occurring. The first cats were probably introduced into eastern Australia in the mid to late eighteenth century. However, no substantial declines in quoll populations occurred until the nineteenth century, after the arrival of foxes and rabbits (Dickman 1996; Abbott 2002; Jones *et al.* 2003). This supports the premise that the Spotted-tailed Quoll may be relatively abundant in Tasmania compared with the mainland due to the absence (until recently) of foxes there (Mansergh 1984). At surveyed sites in New South Wales, foxes were found to be absent from four of the five areas with the highest abundance of Spotted-tailed Quolls, although there was no correlation between the relative abundances of the two species (Catling & Burt 1995). Foxes are also absent from areas of high quoll abundance in north Queensland, although cats and dogs are present (Burnett 2001). However, relatively high densities of Spotted-tailed Quolls have also been recorded in areas where foxes and cats occur in relatively high numbers, and dogs in moderately high numbers (C. Belcher pers. comm.). A study in north-eastern New South Wales found extensive spatial overlap between quolls, foxes and cats, indicating the presence of introduced carnivores does not necessarily

exclude quolls from an area (Glen & Dickman 2008). There is ecological and evolutionary evidence for interspecific competition among the surviving marsupial carnivores of Tasmania (Spotted-tailed Quoll, Eastern Quoll and Tasmania Devil) that may contribute to the natural rarity (compared with other members of the guild) of the Spotted-tailed Quoll in that state (Jones 1997; Jones & Barmuta 1998). On the mainland, it is also possible that competitive interactions with introduced carnivores that occupy a similar prey size niche to Tasmanian Devils may similarly restrict Spotted-tailed Quoll populations.

In all likelihood the impacts of introduced predators on the Spotted-tailed Quoll are likely to be magnified if they occur in conjunction with other threatening processes (Burnett 1993). For example, the distribution and abundance of foxes appears to be associated with patterns of severe land disturbance (Catling & Burt 1995), hence the impacts of habitat degradation and fragmentation on quoll populations are likely to be further compounded by impacts of fox predation and competition. Impacts of introduced predators are also likely to be magnified if two or more species occur in sympatry with Spotted-tailed Quolls (Burnett 2001).

Deliberate killing

Spotted-tailed Quolls are frequently subjected to persecution from landholders, largely in response to their raids on poultry runs, often involving repeated visits until the prey source is depleted (Fleay 1932, 1948; Green & McGarvie 1971; Green & Scarborough 1990; Burnett 1993; Watt 1993; Burnett 2001; Burnett & Marsh 2004). In one extreme case, a farmer in Tasmania is reported to have killed at least 20 Spotted-tailed Quolls annually in his poultry yard (N. Mooney pers. comm.). The public perception of the species is such that some landholders have reported that they would shoot, poison or trap quolls on their property regardless of whether or not the quolls were threatening livestock (Watt 1993). Such persecution is likely to be fuelled by a lack of public understanding about the species and a level of misinformation – a survey in southern Queensland found nearly half of all respondents thought Spotted-tailed and Northern Quolls were introduced fauna (Watt 1993).

The impact of this persecution at a population level is not known, but, given the species is sparsely dispersed, wide-ranging and particularly attracted to poultry yards, may be sufficient to cause serious population declines (Burnett 1993). These declines are likely to be most detrimental to populations that are already small. The last records of *D. m. gracilis* from three areas in northern Queensland were of animals killed when raiding fowl yards (Burnett 1993). The demise of the species on King Island in the early 1900s was also largely attributed to human persecution (Green & McGarvie 1971). Human persecution of quolls will potentially occur wherever quoll habitat abuts urban and rural areas (Andrew 2005). The clearing and continued fragmentation of Spotted-tailed Quoll habitat is likely to increase the incidence of human encounters with quolls and potentially the incidence of persecution.

Road mortality

Like other large carnivorous marsupials, Spotted-tailed Quolls are susceptible to road mortality because they scavenge the carcasses of other road-killed fauna (Burnett 1993; Jones *et al.* 2003). Males, particularly dispersing juveniles, are probably at greatest risk because their extensive ranging behaviour means they encounter roads more frequently (Green & Scarborough 1990; Jones *et al.* 2003). In some areas Spotted-tailed Quolls experience a high incidence of road mortality (Green & Scarborough 1990; Burnett 1993; Jones & Rose 1996; Maxwell *et al.* 1996; Burnett & Marsh 2004; Andrew 2005). In Tasmania, an estimated 1–2 Spotted-tailed Quolls are killed each day along the main road that runs from Hobart to the north-west of the State (N. Mooney pers. comm.). In New South Wales, road deaths accounted for 2 of 18 recorded quoll deaths from a total of 57 radio-collared animals over a two year period (Körtner *et al.* 2003). The northern subspecies of Spotted-tailed Quoll also uses roads as latrine sites, further exacerbating the risk of road mortality (Burnett 2001; Burnett & Marsh 2004). At a population level, road mortality has had a significant impact on other carnivorous marsupials (Orell & Morris 1994; Jones 2000; Oakwood 2000), and it is therefore also likely to be a significant factor in the decline of some Spotted-tailed Quoll populations.

Wildfire and prescription burning

There is scant information available on the effects of wildfire and prescribed burning on Spotted-tailed Quolls. In southern New South Wales about 30% of individuals were known to survive the immediate impact of a severe wildfire (Dawson 2005), while in the north of the State a

population still occupied an area one year post-fire, although individuals were in poor condition (M. Oakwood pers. comm.). Quolls were present in areas that were burnt by two high intensity wildfires in state forest in north-eastern New South Wales, although no quoll was observed to have its entire home range burnt (Glen & Dickman 2006a). Long-term post-fire mortality is likely to be influenced by the availability of prey and refugia to provide protection from predation. Northern Quolls *Dasyurus hallucatus* were found to suffer high predation rates in areas with reduced vegetation cover resulting from frequent fires, compared to individuals in rocky habitats with abundant refugia (Oakwood 2000). Prey resources are likely to be influenced by fire intensity (Fox & McKay 1981; Lunney *et al.* 1987; Driessen *et al.* 1991) and this may in turn affect the subsequent fecundity of Spotted-tailed Quolls and exacerbate competitive interactions with other predators. Despite these potential fire-related threats to Spotted-tailed Quolls, fires can also be beneficial in that they hasten the formation of tree hollows used by the species and its prey (Inions *et al.* 1989; Gibbons & Lindenmayer 2002).

Poisoning by Cane Toads

The Chuditch (or Western Quoll) *Dasyurus geoffroii* and Northern Quoll are both known to be killed from poisoning by the introduced Cane Toad *Bufo marinus* (Covacevich & Archer 1975) and consequently the Spotted-tailed Quoll is also likely to be susceptible. Extensive declines in Northern Quoll populations have been attributed to invading Cane Toads (Oakwood 2004), increasing concerns for the Spotted-tailed Quoll. A projected assessment of the susceptibility of Spotted-tailed Quolls to Cane Toads, based on their potential distributional overlap, micro-habitat use and diet, indicates that the northern subspecies of Spotted-tailed Quoll is at high risk of severe population declines and that the southern mainland subspecies is at moderate risk (Burnett 1997). Rising temperatures due to climate change could enable the Cane Toad to spread further south into New South Wales, exposing a greater number of quoll populations to poisoning risk (Burnett 1997; Andrew 2005). However, in northern and southern Queensland a number of Spotted-tailed Quoll populations persist in areas populated by Cane Toads, and there is no evidence as yet to suggest that poisoning from Cane Toads is a factor in population declines (Burnett 1993; Watt 1993). An action proposed in this Recovery Plan is to investigate the impact of Cane Toads on Spotted-tailed Quolls.

Climate change

Climate changes that are predicted to occur as a consequence of increasing greenhouse gas levels in the atmosphere are likely to result in habitat modification (Howden *et al.* 2003), with fragmented populations of the northern subspecies of the Spotted-tailed Quoll that occupy highland rainforest habitats being particularly at risk (Burnett 2001; Jones *et al.* 2003). Habitat models have suggested that a 1ºC increase in average temperatures will decrease the area of this habitat type by 50% (Hilbert *et al.* 2001). Forecast increases in average temperatures are of 0.1 to 0.5ºC per decade, resulting in a 0.4 to 2ºC change by 2030 (relative to 1990) (CSIRO – www.dar.csiro.au/publications/projections2001.pdf). Climate change also has the potential to extend the range of pest species such as the Cane Toad. As a result an increased number of Spotted-tailed Quoll populations, such as the northern New South Wales populations, would be exposed to this poisonous species (Burnett 1997; Andrew 2005).

Areas and Populations Under Threat

The threatening processes thought to be responsible for the decline of the Spotted-tailed Quoll are broadscale threats that are generally applicable to a wide range of areas within the species' distribution. Consequently, determining the relative threat status of specific areas or populations is often difficult. Small, isolated populations are at risk of extinction due to stochastic and deleterious genetic effects combined with their reduced capacity to overcome elevated mortality rates associated with threatening processes. However, insufficient survey work has been conducted throughout the species' range to allow the identification of all such populations. The isolated, restricted distribution and apparent decline of the northern subspecies (Burnett 1993) mean that remaining populations have an elevated extinction risk. It is also predicted that the high altitude habitat of this subspecies is likely to be significantly modified by future climate changes (Hilbert *et al.* 2001; Jones *et al.* 2003). Populations that are regarded as being at particular risk due to low population sizes and ongoing landuse practices are in the Atherton, Great Basalt Wall and Paluma regions, although the lack of records in this latter region since the 1940s suggests this population is possibly extinct.

Populations in state forests (and other commercially harvested native forests) will experience a high level of habitat disturbance compared to populations in parks and reserves. The level of threat posed by these disturbance regimes has not yet been quantified. If Cane Toads are found to pose a real threat to Spotted-tailed Quolls then quoll populations within the range of Cane Toads (Queensland and northern New South Wales) will be threatened.

Spotted-tailed Quoll populations adjacent to areas of human habitation are likely to have an elevated threat status due to a combination of threatening processes including increased habitat loss and fragmentation, road mortality, deliberate killing, and predation by domestic dogs and possibly cats. For example, quoll populations in some coastal regions of northern New South Wales are considered to be threatened by continuing urbanisation (Andrew 2005). Spotted-tailed Quoll populations, particularly those on forested freehold land or adjacent to freehold land, as well as in other areas, may be at risk from 1080 baiting programs for introduced carnivores where baits are either aerially deployed or surface laid (i.e. baits are not buried). These methods of bait deployment are currently utilised in some areas of Queensland, New South Wales and South Australia.

Recovery Information

Program Implementation

The Recovery Plan will run for five years from the time of adoption and will be managed by a national Recovery Team, comprising representatives from the agencies and organisations with an interest in, and responsibility for, Spotted-tailed Quoll conservation. The Recovery Team will coordinate implementation of the Recovery Plan. Regional operations groups will be established where required to prepare work plans, and direct and monitor regional recovery actions. Each operations group will be represented by at least one person on the recovery team. Any technical, scientific, habitat management or education issue requiring skills not available within the Recovery Team will be referred to specialist organisations and individuals as appropriate. Implementation of individual actions will remain the responsibility of the relevant agencies and organisations identified in the Recovery Plan (subject to available resources), who will be responsible for preparing work plans and monitoring progress toward recovery within their own jurisdiction.

Program Evaluation

The Recovery Team will be responsible for informal evaluation annually. Towards the termination of the Recovery Plan, an external reviewer will be appointed to undertake a formal review and evaluation of the recovery program.

Recovery Objectives

The **Overall Objective** of recovery is to increase knowledge of the distribution, ecology, status of populations, and impact of threatening processes on Spotted-tailed Quoll populations and to reduce the impact of threatening processes throughout the species' range and subsequently halt the current decline in its distribution and abundance.

Within the life span of this Recovery Plan, the **Specific Objectives** listed below have been identified as necessary to guide the recovery of the Spotted-tailed Quoll. The recovery actions and performance criteria for each of these objectives are outlined in the following section.

1. Determine the distribution and status of Spotted-tailed Quoll populations throughout the range.
2. Increase knowledge of the biology and ecology of the Spotted-tailed Quoll throughout its range to refine management of the species and its habitat.
3. Reduce the rate of habitat loss and fragmentation on private land.
4. Evaluate and manage the risk posed by silvicultural practices.

5. Determine and manage the threat posed by introduced predators (foxes, cats, wild dogs) and of predator control practices on Spotted-tailed Quoll populations.
6. Determine and manage the impact of fire regimes on Spotted-tailed Quoll populations.
7. Reduce deliberate killings of Spotted-tailed Quolls.
8. Reduce the frequency of Spotted-tailed Quoll road mortality.
9. Assess the threat Cane Toads pose to Spotted-tailed Quolls and develop threat abatement actions if necessary.
10. Determine the likely impact of climate change on Spotted-tailed Quoll populations.
11. Increase community awareness of the Spotted-tailed Quoll and involvement in the Recovery Program.

Recovery Objectives, Performance Criteria and Actions – Summary

Objective	Performance Criteria	Actions
1. Determine the distribution and status of Spotted-tailed Quoll populations throughout the range.	Knowledge of the species' distribution and the status of populations is increased and the information used for conservation management.	1.1 Develop targeted survey techniques and monitoring protocols. 1.2 Undertake field surveys and mapping in areas where the distribution and status of populations are poorly known. 1.3 Develop and implement a program to monitor Spotted-tailed Quoll population status at representative sites throughout the species' range.
2. Increase knowledge of the biology and ecology of the Spotted-tailed Quoll throughout its range to refine management of the species and its habitat.	Information on population genetics, demographics and habitat quality obtained and used for conservation planning and management.	2.1 Develop a standard data collection protocol for live-trapping studies. 2.2 Conduct genetic analyses to determine genetic variation between populations and identify appropriate genetic management units. 2.3 Undertake genetic analysis of all captive animals and ensure their genetic profile is adequately documented. 2.4 Determine measures of habitat quality. 2.5 Investigate population demographics, particularly age-specific survival rates, juvenile dispersal and reproductive life span, to facilitate population viability modelling and conservation management.
3. Reduce the rate of habitat loss and fragmentation on private land.	Increased protection of Spotted-tailed Quolls and their habitat on private land and efforts to increase habitat connectivity commenced.	3.1 Target landholders in areas where Spotted-tailed Quolls are known to occur to protect and manage their land in a manner that is compatible with maintenance of Spotted-tailed Quoll habitat, through voluntary conservation agreements. 3.2 Maintain and restore habitat corridors on unprotected freehold land. 3.3 Develop guidelines to reduce the impact of urban development on Spotted-tailed Quolls and disseminate to local councils in areas where quolls occur.
4. Evaluate and manage the risk posed by silvicultural practices.	The impact of silvicultural practices on Spotted-tailed Quolls is determined and management prescriptions developed and incorporated into timber harvesting practices.	4.1 Develop guidelines on minimum habitat requirements that can be used to direct the formation of habitat retention prescriptions in commercially harvested forests. 4.2 Determine disturbance thresholds of female Spotted-tailed Quolls to develop habitat retention prescriptions in harvested areas. 4.3 Implement monitoring programs to evaluate the effectiveness of current habitat retention prescriptions at providing habitat for viable populations of Spotted-tailed Quolls in commercially harvested forests.

Objective	Performance Criteria	Actions
5. Determine and manage the threat posed by introduced predators (foxes, cats, wild dogs) and of predator control practices on Spotted-tailed Quoll populations.	Information on the impact of introduced predators and predator control practices on Spotted-tailed Quoll populations obtained and alternative control methods and bait delivery techniques investigated and used for conservation management.	5.1 Investigate interactions between Spotted-tailed Quolls and introduced predators to determine the impact on quoll populations. 5.2 Monitor the abundance of Spotted-tailed Quolls and introduced predators in areas with and without predator control programs. 5.3 Conduct PVA to investigate the impact of increased mortality resulting from baiting practices on the long-term viability of Spotted-tailed Quoll populations throughout their range. 5.4 Review the impact of strychnine on Spotted-tailed Quolls and its use in areas of known or potential quoll habitat. 5.5 Investigate alternative livestock protection methods that have fewer impacts on non-target species. 5.6 Review existing information on alternative poison delivery or biological control systems to identify systems with high target species specificity.
6. Determine and manage the impact of fire regimes on Spotted-tailed Quoll populations.	Information on the impact of fire regimes obtained and used for conservation management.	6.1 Incorporate the protection of rocky outcrops and riparian zones into fire management plans within areas of known Spotted-tailed Quoll habitat. 6.2 Investigate the impact of wildfires and prescription burns on Spotted-tailed Quoll populations.
7. Reduce deliberate killings of Spotted-tailed Quolls.	Deliberate killings of Spotted-tailed Quolls reduced through improved landholder knowledge of the species and an increase in the number of quoll-proof poultry runs in areas with a prevalence of direct killings.	7.1 Prepare/update brochures on constructing effective 'quoll-proof' poultry runs and aviaries and disseminate to landholders in areas where Spotted-tailed Quolls are known to occur, together with information on the species' ecology and threatened status.
8. Reduce the frequency of Spotted-tailed Quoll road mortality.	Spotted-tailed Quoll road deaths reduced by identifying hotspots and implementing effective mitigation measures in these areas.	8.1 Identify sections of road where Spotted-tailed Quolls are frequently killed. 8.2 Review existing information, and monitor existing mitigation measures to identify the most effective mitigation actions for reducing road deaths. 8.3 Develop and implement mitigation measures at road-kill hotspots.
9. Assess the threat Cane Toads pose to Spotted-tailed Quolls and develop threat abatement actions if necessary.	Populations most likely at risk from Cane Toads identified and monitoring commenced to assess threat. Threat abatement actions developed if necessary.	9.1 Map the current distribution of Spotted-tailed Quolls and Cane Toads to identify areas of overlap and quoll populations most at risk and include at least two 'at risk' populations in long-term monitoring programs (Action 1.3). 9.2 Monitor the survival of Spotted-tailed Quolls in areas newly colonised by Cane Toads. 9.3 If, based on investigations in 9.1 and 9.2, it is considered that Cane Toads are a threat to quoll populations, devise & implement appropriate threat abatement actions.

Objective	Performance Criteria	Actions
10. Determine the likely impact of climate change on Spotted-tailed Quoll populations.	Populations most likely at risk from climate change identified and included in monitoring program (Action 1.3).	10.1 Identify and map populations considered to be 'at risk' from habitat alterations resulting from climate change. 10.2 Include at least two identified 'at risk' populations in long-term monitoring programs (Action 1.3).
11. Increase community awareness of the Spotted-tailed Quoll and involvement in the Recovery Program.	Communication strategy developed and educational resources compiled and disseminated to identified target audience.	11.1 Conduct a survey to determine the target audience and avenues for raising public awareness, and develop a communication and public education strategy based on the findings. 11.2 Compile education resources and distribute these to the identified target audience. 11.3 Involve the community in survey and monitoring efforts for the species. 11.4 Erect information plaques at Spotted-tailed Quoll displays in captive facilities (e.g. zoos, sanctuaries) to increase public awareness of the species and its conservation plight.

Implementation Costs

Table 2. Implementation costs by year - summary

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Total	$1,827,000	$2,502,000	$2,583,000	$1,644,000	$1,224,000	$9,780,000

The estimated cost of implementing the Recovery Plan is $9.75 million over five years.

Role and Interests of Indigenous People

The Spotted Tailed Quoll is a culturally and spiritually significant species to Aboriginal people, especially in Queensland. The species is represented in the Dreamtime through totemism, country and story for many communities in Queensland, where Aboriginal people wish to be actively involved in the management and protection of the Spotted Tailed Quoll at every level. A loss of the species through further fragmentation of its range and numbers will directly impact upon country, culture and spirituality. Indigenous communities on whose traditional lands the Spotted Tailed Quoll occurs will be advised, through the relevant regional Indigenous facilitator, of the preparation of this Recovery Plan and invited to provide comments if so desired. Indigenous communities will be invited to be involved in the implementation of the Recovery Plan.

Biodiversity Benefits

The implementation of this recovery plan will have benefits for a wide range of flora and fauna communities throughout the range of the Spotted-tailed Quoll. As a large forest-dependent carnivore that occurs in a wide range of forest types, the conservation of the Spotted-tailed Quoll requires the protection of extensive tracts of forest, along with the prey species this habitat supports. To achieve this, habitat management must be approached at a landscape level to link habitat both on and off reserve. The flow-on conservation benefits this will provide for other fauna species as well as a wide range of vegetation communities, makes the Spotted-tailed Quoll an 'umbrella' species whose long-term conservation will, by default, achieve broader conservation goals. For example, maintenance of the species' wide prey base and denning resources requires the development of forest management practices that ensure the retention of sufficient hollow bearing trees, fallen logs and a complex habitat structure. This will benefit threatened and non-threatened fauna, particularly hollow-dependent birds and mammals and other large carnivores such as forest owls, goannas and pythons.

Actions that are proposed in this Recovery Plan to minimise human-induced impacts on Spotted-tailed Quolls will also benefit other native fauna. In particular, developing and encouraging the use of a predator-proof poultry yard design (Action 7.1) is likely to reduce human persecution of Spotted-tailed Quolls as well as other native species that are known predators of domestic poultry such as pythons, goshawks and goannas. The exclusion of these predators from poultry yards will result in them being viewed less as pests and will foster an attitude amongst landholders which is more conducive to the development of an appreciation of their positive values as wildlife. In some areas Spotted-tailed Quolls are known to experience a high incidence of road mortality. The implementation of actions to reduce Spotted-tailed Quoll road deaths (Action 8.3) such as the development of road underpasses and the removal of carcasses from the road surface may also reduce the incidence of road deaths of a range of other native species.

For several reasons the Spotted-tailed Quoll constitutes an excellent 'flagship species' whose profile can be used to highlight the conservation issues facing forest fauna and ecosystems generally. Being a relatively large mammal with a distinctive, striking physical appearance, the species readily fits the profile of other charismatic fauna that capture the public's interest. From a biological perspective, the conservation issues relevant to the Spotted-tailed Quoll include a range of broad conservation and biodiversity issues such as land clearing, habitat degradation,

sustainable land-use practices and the threats posed by exotic species. These are issues that are also relevant for the conservation of a wide range of other species of fauna and flora.

Social and Economic Impacts

The implementation of this Recovery Plan will convey various social and economic benefits and costs. The economic costs of this plan will be predominantly associated with the implementation and monitoring of altered forest management practices and habitat retention prescriptions (Actions 4.1–4.3), predator control practices (Actions 5.1–5.6) and road-kill mitigation measures (Action 7.1).

Although habitat retention prescriptions already exist in commercially harvested forests within the range of the Spotted-tailed Quoll, it is not known whether these prescriptions contribute effectively to the conservation of the species and its habitat. The outcomes resulting from the implementation of this Recovery Plan associated with the development and implementation of effective habitat management prescriptions (Actions 3.3, 4.1 and 6.1) may have some negative social and economic impacts on the timber industry. These negative impacts are likely to vary considerably across the species' range and will depend on the silvicultural systems being utilised and the conservation measures currently in place. However, there are significant positive impacts that may result from the implementation of these actions including the maintenance of forest biodiversity, and a more ecologically sustainable forest industry. The protection and sustainable management of large tracts of forested habitat will also contribute to the growth of the ecotourism industry in eastern Australia.

There may be economic costs associated with the implementation of actions to reduce the impacts of poison baiting programs on Spotted-tailed Quoll populations (Action 5.4). The cost of conducting these programs will increase if bait deployment methods become more labour intensive. This is particularly relevant in areas where baits are currently either aerially deployed or surface laid. However, the use of more target-specific methods of bait delivery will have positive outcomes for non-target species and increase the effectiveness of these programs at reducing target populations, making them more cost effective. The development and implementation of best-practice baiting protocols (Action 5.6) which are able to achieve and sustain reduced target predator numbers, may require significant financial investment. However, the resulting system will maximise the efficacy and target specificity of predator control programs, achieving positive biodiversity and domestic stock production outcomes.

The implementation of road-kill mitigation measures (Actions 8.1–8.3) that require additional infrastructure, such as fauna underpasses, will require an additional commitment of financial resources. Such measures will be particularly important in areas that support relatively high quoll densities and are bisected by roads that carry significant traffic loads. These measures may become increasingly important if road infrastructure and traffic flows in rural areas increase to meet the requirements of the expansion of human populations into these areas. Social and economic benefits that may result from the implementation of these actions include reduced collisions between vehicles and wildlife and the associated trauma, and a reduction in the road deaths of many other fauna species.

In addition to the benefits outlined above, it is anticipated that this Recovery Plan's emphasis on public education (Actions 11.1–11.4) will be socially beneficial in producing a more informed community, with a greater appreciation and understanding of Australia's native fauna and of the conservation issues affecting these fauna. This Recovery Plan will also facilitate communication between scientists and stakeholders and lead to a more coordinated approach to quoll research and management.

Management Practices

The recovery of the Spotted-tailed Quoll is primarily dependent on the protection of its existing habitat. Practices or developments that destroy this habitat, or alter it to the extent that the species' density is reduced, will be detrimental to the conservation of the species. In particular, any further clearance or fragmentation of habitat should be avoided, as should forestry practices or burning regimes that exceed the habitat disturbance threshold of the species. Practices that directly or indirectly reduce the density of prey within a habitat patch also have the capacity to

affect the density of Spotted-tailed Quolls and the ability of the habitat to support breeding females. Consequently, the spatial and temporal scale of such practices must be managed so that the density of Spotted-tailed Quolls in the landscape is not reduced. Habitat retention prescriptions for the Spotted-tailed Quoll currently exist for all commercially harvested forests within the species' range. These prescriptions vary throughout the species' range and include the reservation of large patches of suitable habitat, the retention of smaller patches of habitat to protect particular features such as den or latrine sites (communal defaecation sites), the retention of strips or corridors of habitat such as streamside reserves, and the protection of small patches of habitat or single trees within the harvested area. However, whether these prescriptions contribute effectively to the conservation of populations in these forests, is unknown. Research to determine habitat disturbance threshold parameters of the species (Action 4.2) is required, so that Spotted-tailed Quoll habitat can be sustainably managed. Monitoring of populations in forests where habitat retention prescriptions aimed at conserving the species and its habitat have been implemented (Action 1.3), will inform managers whether these measures are contributing effectively to the conservation of the Spotted-tailed Quoll.

There are no mitigating measures that can reduce the immediate impact of habitat clearance on Spotted-tailed Quoll populations. In the long-term, revegetation of equivalent-sized areas may prevent net habitat loss; however, the benefits of this habitat will not be fully realised until the forest has matured to support a full complement of prey species and den sites. Based on the formation of tree hollows, this may not be for at least 120-180 years (Gibbons & Lindenmayer 2002). Consequently, any clearance of habitat can be viewed as having serious long-term implications for Spotted-tailed Quolls.

Practices that increase the exposure of Spotted-tailed Quolls to the identified threatening processes will also be detrimental to the species. The construction of roads through Spotted-tailed Quoll habitat, for example, is unlikely to contribute significantly to habitat fragmentation effects; however, the potential increase in the incidence of Spotted-tailed Quoll road mortality may contribute to population declines. Increases in the flow and/or speed of traffic on existing roads through or adjacent to Spotted-tailed Quoll habitat is likely to further increase mortality rates (Jones 2000) and should be restricted. Roads and other forms of habitat disturbance may also promote increased infiltration of foxes (Catling & Burt 1995), and possibly other introduced carnivores, potentially increasing the competitive and predatory pressure on Spotted-tailed Quolls. Increasing urbanisation on habitat fringes will also increase the exposure of quolls to predation by domestic pets, and to human persecution. Additionally, increases in human habitation adjacent to Spotted-tailed Quoll habitat is likely to be accompanied by requests to manage the fringing habitat in a manner that protects human interests. In particular, baiting and trapping of feral animals to protect domestic stock and fuel reduction practices such as burning and grazing are likely to occur in the fringing bushland.

In summary, the impacts of increasing urbanisation can be reduced if:

- Conservation objectives for the Spotted-tailed Quoll are considered in urban planning and zoning decisions;
- The public are educated about appreciating and tolerating Spotted-tailed Quolls;
- Restrictions are placed on the keeping of domestic cats and dogs;
- Quoll-proof poultry yards and aviaries are used;
- Mitigating measures are incorporated into roads and road-killed carcasses are removed from the road surface;
- Target-specific feral animal control programs are used; and
- Vegetation corridors connecting habitat patches are retained and enhanced, or created.

In all States and Territories where the Spotted-tailed Quoll occurs, the use of 1080 is guided by best practice guidelines or operational procedures (DEH 2004a). The Department of the Environment and Heritage's *Administrative Guidelines on Significance Supplement for the Tiger Quoll (Southeastern Mainland Population) and the Use of '1080'* provides guidelines for the use of 1080 in pest animal control programs in areas that are either occupied or potentially occupied by Spotted-tailed Quolls. Due to the potential for some '1080' baiting programs to pose a

significant threat to Spotted-tailed Quoll populations, particularly populations that are small and isolated, proponents of such actions are required to refer the proposed action to the Australian Government Environment Minister for a decision as to whether assessment and approval is required. Activities such as aerial baiting or broadscale surface baiting, which are used to control wild dogs and dingoes in areas where Spotted-tailed Quolls are either known to occur or may potentially occur, may require approval unless measures are adopted that sufficiently minimise any likely impacts on the species. It is recommended that these methods be used only in areas where it can be demonstrated that there is a low risk to Spotted-tailed Quolls (DEH 2004a). Burying baits under the ground to a minimum depth of 10 cm has been found to greatly reduce their uptake by Spotted-tailed Quolls (Belcher 1998; Murray 1998). Ground baiting programs where baits are buried at a depth of greater than 10 cm do not require a referral (DEH 2004a).

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