

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

Department of Environment, Land, Water and Planning



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Environment, Land,  
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Tasmanian  
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**ACT**  
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This Recovery Plan was prepared by the Victorian Department of Environment, Land, Water and Planning (DELWP), with Kirstin Long and Jenny Nelson (DELWP) as lead contributors. 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:** Female Spotted-tailed Quoll *Dasyurus maculatus* by Jenny Nelson.

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## Summary

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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. This recovery plan will be adopted for *D. m. gracilis*, *D. m. maculatus* (southeastern mainland population) and *D. m. maculatus* (Tasmanian population). 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, bushfire 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. The strategy for recovery will be to focus on reducing the impact of threatening processes throughout the species' range and subsequently halt the current decline in its distribution and abundance. Increasing knowledge of the distribution and status of populations, the impact and management of threatening processes, and investigation of key biological and ecological attributes is also required to facilitate recovery.

## Species Information

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### 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.* 2004). 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).

### Taxonomy

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). General references to the 'Spotted-tailed Quoll' in the text refer to all subspecies, unless specified otherwise.

## Biology and ecology

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 (NSW) (Burnett 2001; Jones *et al.* 2003; Körtner *et al.* 2004; Andrew 2005), and five years in southern NSW 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 2007a). Although breeding may not always occur in successive years, most females produce a litter annually (Burnett 2001; Belcher 2003; Andrew 2005; Nelson 2007a). The average litter size is five young (Settle 1978; Edgar & Belcher 1995; Burnett 2001), although there is some evidence of high mortality during the period from birth until weaning (Fleay 1948; Belcher 2003). However, 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 2007a). 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 vary 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).

## Conservation status

Since European settlement, the Spotted-tailed Quoll has declined in both distribution and abundance. Populations have become fragmented and isolated and the mainland range has been reduced by 50–90% (Jones *et al.* 2001). This has resulted in the species being listed as threatened in every state and territory in which it occurs.

At the national level, *D. m. gracilis* and *D. m. maculatus* (southeastern mainland population) are listed as Endangered and *D. m. maculatus* (Tasmanian population) is listed as Vulnerable under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*.

In 2004, *D. m. maculatus* (southeastern mainland population) was judged eligible for reclassified from Vulnerable to Endangered under the EPBC Act Criterion 1 – Decline in numbers (DEH 2004a).

**Queensland:** *Dasyurus m. gracilis* is listed as Endangered and *D. m. maculatus* is listed as Vulnerable under the *Nature Conservation Act 1992*.

**New South Wales:** *Dasyurus m. maculatus* is listed as Vulnerable under the *Threatened Species Conservation Act 1995*. The species has been categorised as a 'Landscape' species under the NSW Saving our Species (SoS) program.

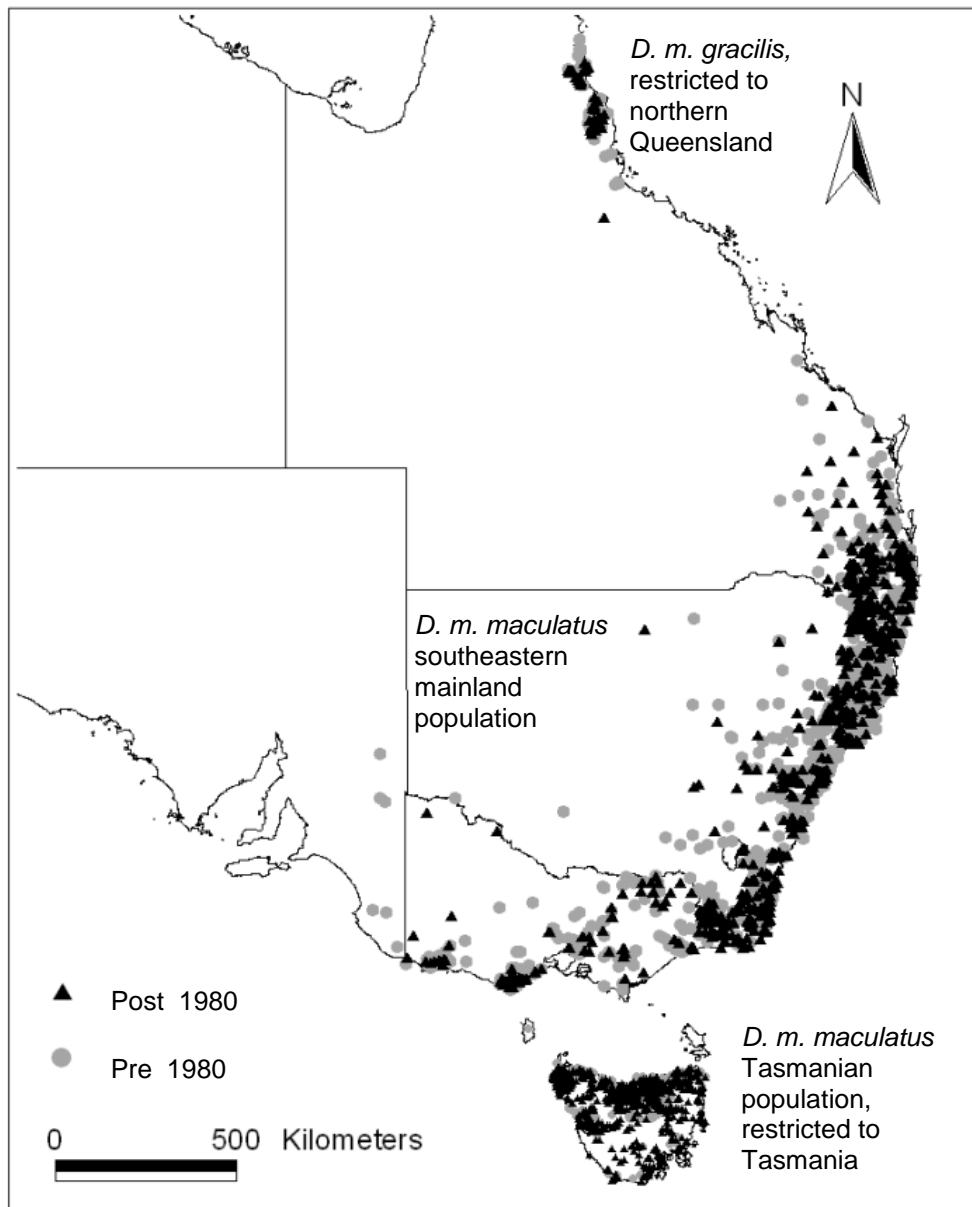
**Australian Capital Territory:** *Dasyurus m. maculatus* is listed as Vulnerable under the *Nature Conservation Act 1980*.

**Victoria:** *Dasyurus m. maculatus* is listed as Threatened under the *Flora and Fauna Guarantee Act 1988* and is considered Endangered (DSE 2013).

**Tasmania:** *Dasyurus m. maculatus* is listed as Threatened under the *Threatened Species Protection Act 1995* and is considered Rare.

**South Australia:** *Dasyurus maculatus* is listed as Endangered under the *National Parks and Wildlife Act 1972*, but is considered to be extinct in that state (DEH 2004a).

## 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 (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 NSW 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; DEH 2004a). 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 2007a). 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 factors that influence habitat quality and to identify and map high quality habitat throughout the species' range (Action 1.3). 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

<b>State</b>	<b>Population</b>	<b>Basis for 'importance' classification</b>
<i>Dasyurus maculatus maculatus</i> 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
	Takone to Upper Natone (south-south west of Burnie)	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
<i>Dasyurus maculatus maculatus</i> southeastern 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
	Northern Tablelands <ul style="list-style-type: none"> <li>• Tenterfield</li> <li>• Glen Innes</li> <li>• Armidale / Walcha</li> <li>• Dorriggo Plateau</li> </ul> Barrington	stronghold & research populations
	North Coast <ul style="list-style-type: none"> <li>• Yuragir</li> <li>• Mariah</li> </ul> Limeburners Creek	research or recovery populations
	Greater Blue Mountains <ul style="list-style-type: none"> <li>• Wolgan</li> <li>• Goulburn River</li> </ul> Jenolan	stronghold & research populations
	South Coast <ul style="list-style-type: none"> <li>• Barren Grounds / Budderoo</li> <li>• Escarpment forests from Morton National Park to Victorian border</li> </ul> Tallaganda / Badja	stronghold & research populations
	Kosciuszko National Park / Snowy Mountains Byadbo	stronghold & research populations



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
<i>Dasyurus maculatus gracilis</i>		
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.

Populations may be classified as being of 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

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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 NSW, 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 NSW, 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 at least halved, and is now highly disjunct (Mansergh 1984). It is most likely extinct from Wilsons Promontory, with the last record from 1960. There have been no records from the Macedon Ranges north west of Melbourne for several decades, and records from the Otway Ranges and the Mount Eccles – Lake Condah area in south-western Victoria are now rare (Backhouse 2003). The only area of Victoria where Spotted-tailed Quolls are now regularly recorded is East Gippsland, particularly the upper Snowy River and tributaries and the Errinundra Plateau area (Mansergh 1995; Nelson 2007b). The Spotted-tailed Quoll is 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); these factors 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 direct killing 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 (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 (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 occurred at an accelerated rate since the late 1980s and was a key driver of land clearance in Tasmania (Kirkpatrick & Jenkin 1995; Tasmanian Planning Commission 2009) until 2010 (FPA 2014). The relatively high rate of habitat loss at that time suggests that the population would have declined, although this has not been quantified (Anon 2001). The estimated total number of mature individuals in Tasmania is considered to be limited, and at risk since a high proportion of core habitat occurs on private land (Troy 2014). Coastal areas of northern NSW are under major pressure from urbanisation, posing a significant threat to the important quoll populations there (Andrew 2005). While Troy (2014) found high densities of Spotted-tailed Quolls on agricultural land in northwestern Tasmania, there was evidence of a heavy reliance on eucalypt forest in this area, with home ranges larger in more fragmented areas and indications of a threshold proportion of forest areas, below which quolls would not be able to inhabit agricultural land. 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 killing 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 past intensive selective logging, but does not occur in areas subjected to extensive clearing and settlement (Burnett 1993). In southern NSW 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 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<sub>50</sub>) is 1.85 mg kg<sup>-1</sup> 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<sub>50</sub> 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 NSW 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 indicate (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).

Widespread strychnine baiting for dingoes has also been implicated in declines of the Spotted-tailed Quoll in NSW 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, NSW and South Australia (Fleming *et al.* 2001).

## Competition and predation from introduced predators

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 the frequency of interactions, or the impact on quoll populations.

Given the dietary and habitat overlap between the Spotted-tailed Quoll and introduced predators (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 (Abbott 2002). 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). At surveyed sites in NSW, 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 NSW found extensive spatial overlap between quolls, foxes and cats, indicating the presence of introduced predators 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 predators 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 deliberate killing 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). 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 deliberate killing 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 deliberate killing 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 poultry yards (Burnett 1993). The demise of the species on King Island in the early 1900s was also largely attributed to deliberate killing by humans (Green & McGarvie 1971). Deliberate killing 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 deliberate killing.

### **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 NSW, 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.

### **Bushfire and prescription burning**

There is scant information available on the effects of bushfire and prescribed burning on Spotted-tailed Quolls. In southern NSW about 30% of individuals were known to survive the immediate impact of a severe bushfire (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 bushfires in state forest in north-eastern NSW, 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 *Rhinella marina* (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 NSW, 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 1°C increase in average temperatures will decrease the area of this habitat type by 50% (Hilbert *et al.* 2001). It is estimated that by 2030 the annual temperature across Australia will have risen by 1.0 °C (above 1990 temperatures), with a warming of 0.7–0.9 °C in coastal areas and 1–1.2 °C inland. A substantial increase in fire weather risk is also likely across most sites in south-eastern Australia (CSIRO: [http://www.climatechangeinaustralia.gov.au/technical\\_report.php](http://www.climatechangeinaustralia.gov.au/technical_report.php)). 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 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 broad-scale 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 land use 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 likely to be 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. 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 NSW 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 where baits are either aerially deployed or surface laid (i.e. baits are not buried). These methods of bait deployment are currently used in some areas of Queensland, NSW and South Australia.



## Recovery Information

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### Strategy for Recovery

The strategy for recovery of the Spotted-tailed Quoll will be to focus on reducing the impact of threatening processes throughout the species' range and subsequently halt the current decline in its distribution and abundance. Increasing knowledge of the distribution and status of populations, the impact and management of threatening processes, and investigation of key biological and ecological attributes is also required to facilitate recovery. Priorities for quoll recovery will differ between states and regions, therefore actions are not presented here in order of priority. However, each action has been allocated as a high, medium or low priority for the national recovery of the Spotted-tailed Quoll. A summary of the relationship between objectives, performance criteria and actions is presented in Table 3.

### 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 end of this 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 reduce the rate of decline of the Spotted-tailed Quoll, and ensure that viable populations remain throughout its current range in eastern Australia.

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, and identify key threats and implement threat abatement management practices.
2. Investigate key aspects of the biology and ecology of the Spotted-tailed Quoll to acquire targeted information to aid recovery.
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 Action Detail

### **Objective 1. Determine the distribution and status of Spotted-tailed Quoll populations throughout the range, and identify key threats and implement threat abatement management actions.**

Action 1.1 Develop targeted survey techniques and monitoring protocols.

*Performance criterion: Standardised survey and monitoring protocols identified for use throughout the species' range.*

Spotted-tailed Quolls occur at low densities over large areas of often remote and rugged terrain, making them a difficult species to survey and monitor. The survey techniques used to detect Spotted-tailed Quolls vary in different areas of the species' distribution and include cage trapping (e.g. Körtner *et al.* 2004; Glen & Dickman 2006a), latrine searches (e.g. Dawson 2005; Dawson *et al.* 2007), camera trapping (e.g. Nelson 2007c; Burnett and Holmes 2008; Nelson *et al.* 2010), and hair-tube surveys (e.g. Jones and Rose 1996; Nelson 2007a). Genetic analysis of DNA extracted from scats collected from latrines (Ruibal *et al.* 2009), and of hair samples collected in hair-tubes (Ruibal *et al.* 2010), provides a means of identifying individual quolls that can be used to estimate abundance without the need for live-capture of individuals. Individual quolls can also be identified from the images obtained by camera trapping (Burnett 2010) which may also allow abundance estimates from these data. A review of survey techniques is required to identify the most appropriate technique, or combination of techniques, and the survey effort needed to detect quolls at a range of population densities. This will help ensure survey data are collected consistently within each region and facilitate a more accurate assessment of the species' distribution and abundance (or an index of this) and allow population trends to be tracked.

**Implementation partners:** Recovery Team.

**Priority:** High

Action 1.2 Undertake field surveys and mapping in areas where the distribution and status of populations are poorly known.

*Performance criterion: An increase in knowledge of the current distribution and status of populations.*

The distribution and status of many Spotted-tailed Quoll populations throughout the species' range are poorly known. Accurate distributional data are needed to prioritise management actions and provide baseline data against which population changes can be tracked. Field surveys using standardised methods identified in Action 1.1 will be undertaken to determine distribution and population status (i.e. resident population or occasional records in these areas). Genetic samples collected during field surveys would provide material for population structure analyses to inform Action 2.2. Survey data will be mapped to provide an accurate map of current distribution that will help identify areas of important habitat for Spotted-tailed Quoll populations.

**Implementation partners:** Office of Environment & Heritage NSW; Dept. Environment & Heritage Protection QLD; Dept. Environment, Land, Water & Planning VIC; Dept. Primary Industries, Parks, Water & Environment TAS; Environment and Planning Directorate ACT.

**Priority:** High

Action 1.3 Develop and implement a program to monitor Spotted-tailed Quoll population status, determine factors influencing habitat quality, identify threats and implement management actions at representative sites throughout the species' range.

*Performance criterion: Factors influencing distribution and abundance identified and management actions implemented to mitigate threats at key sites throughout the range.*

Changes in the status and distribution of populations are likely to reflect population trends and to provide a measure of the recovery of the Spotted-tailed Quoll. Study sites will be identified in a range of habitat types throughout the species' range for long-term monitoring using a standardised protocol across all sites. Monitoring programs should be rigorously designed to ensure adequate power to detect a specified level of change in the population index. Populations targeted for monitoring should include stronghold populations as well as other less secure populations, as these are likely to be more susceptible to anthropogenic and other

disturbances. Populations for which data already exist should also be targeted to facilitate the identification of longer term trends. Data should also be collected concurrently on factors that may influence the abundance of Spotted-tailed Quolls in these areas, such as habitat structure and extent, prey densities, introduced predator abundance and current management. This will enable high quality habitat, or habitat that is critical to the survival of the species, to be identified and mapped. This information can also be used to assess which factors are likely to contribute to quoll declines. Where possible, implement management actions that may mitigate those factors (e.g. introduced predator control, timber harvesting prescriptions, fire management). A formal risk assessment process could be used to help prioritise management responses for each population. The identified important populations should be strongly represented in this monitoring program, especially those populations having high animal abundance, as this will help determine those habitat attributes important in supporting high quoll abundance.

**Implementation partners:** Office of Environment & Heritage NSW; Dept. Environment & Heritage Protection QLD; Dept. Environment, Land, Water & Planning VIC; Dept. Primary Industries, Parks, Water & Environment TAS; Environment and Planning Directorate ACT, Recovery Team, operational groups.

**Priority:** High

## **Objective 2. Investigate key aspects of biology and ecology of the Spotted-tailed Quoll to acquire targeted information to aid recovery.**

Action 2.1      Develop a standard data collection protocol for live-trapping studies.

*Performance criterion: Standard data collection protocol developed for live-trapping studies.*

To increase knowledge of the biology of the Spotted-tailed Quoll, a standard data collection protocol will be developed for live-trapping studies. It is intended that this protocol will recommend minimum data collection requirements for field staff working on independent research projects. This will maximise the collection of relevant, comparable biological information, with minimal additional effort, across a broad range of sites. These data will increase knowledge of population demography and health in different geographic areas and habitats, and facilitate the collection of genetic samples. Such data will also facilitate Population Viability Analysis (PVA), which can be used to assess the long-term viability of Spotted-tailed Quoll populations, identify gaps in existing knowledge and assess management options (Possingham *et al.* 1993).

**Implementation partners:** Project officer.

**Priority:** Medium

Action 2.2      Conduct genetic analyses to determine genetic variation between populations and identify appropriate genetic management units.

*Performance criterion: Genetic management units identified.*

Research to date has identified Tasmanian Spotted-tailed Quoll populations as belonging to a separate Evolutionarily Significant Unit (ESU) to mainland populations, while the northern Queensland populations were identified as belonging to a separate Management Unit (MU) within the same ESU as the remaining mainland populations (Firestone *et al.* 1999). Continued research is required to establish the genetic diversity within and between populations, allowing the further identification of genetic management units. This will highlight populations that are genetically isolated as a result of habitat fragmentation and inform future management actions to maintain genetic diversity (Firestone *et al.* 2000; Cardoso *et al.* 2009). Population structure analyses of DNA samples collected during field surveys conducted under Action 1.2 could be used to inform the differentiation of genetic management units. A recent study that investigated the genetic status of the isolated south-west Victorian population and compared it with samples from populations from south-eastern NSW and other regions of Victoria found that the mainland populations form a single ESU and the Victorian populations one MU. The results also indicated that populations exhibited evidence of genetic bottlenecks and were declining (Belcher 2006).

**Implementation partners:** Office of Environment & Heritage NSW; Dept. Environment & Heritage Protection QLD; Dept. Environment, Land, Water & Planning VIC; Dept. Primary Industries, Parks, Water & Environment TAS; Environment and Planning Directorate ACT.

**Priority:** Medium

**Action 2.3** Undertake genetic analysis of all captive animals and ensure their genetic profile is adequately documented to facilitate the maintenance of a genetically representative and diverse captive population.

*Performance criterion: Genetic analysis of captive animals undertaken and genetic profiles documented and used to inform breeding programs.*

Spotted-tailed Quolls are currently housed at a number of Australian zoos and wildlife parks for the purpose of public display, research and captive breeding. Featherdale Wildlife Park (NSW) takes the lead role in the management and breeding of captive individuals. There are a number of other institutions that also have captive colonies that are registered in the breeding studbook (e.g. Healesville Sanctuary (VIC), Phillip Island Wildlife Park (VIC), Ballarat Wildlife Park (VIC), Gorge Wildlife Park (SA), and Brisbane Forest Park (QLD)). Several Tasmanian wildlife parks are participating in a coordinated captive breeding program. Separate management of mainland and Tasmanian Spotted-tailed Quolls should continue to be practised to preserve the genetic integrity of captive populations. Although the translocation of captive-bred animals into the wild is not anticipated to play a role in the recovery of the species within the life of this Recovery Plan, the maintenance and correct management of captive populations should, however, ensure healthy and genetically diverse source populations are available if this becomes a necessary recovery action in the future. Undertaking genetic analysis of all captive animals and ensuring their origins and genetic profiles are documented will facilitate the maintenance of genetically diverse captive populations.

**Implementation partners:** Recovery team, captive management institutions.

**Priority:** Low

**Action 2.4** Investigate population demographics, particularly age-specific survival rates, juvenile dispersal and reproductive life span, to facilitate population viability modelling and conservation management.

*Performance criterion: Demographic data collected for at least three Spotted-tailed populations for use in PVA to facilitate management.*

Knowledge of population demographic parameters, such as age-specific mortality, juvenile dispersal and reproductive life span, are vital in understanding and managing Spotted-tailed Quoll populations. When this information is reliably determined, it can be used in PVAs, making the models produced significantly more useful in aiding management decisions. Some relevant data have been obtained for populations in NSW which have been the subject of long-term research projects, and PVAs are currently being developed to investigate the potential impact on populations of elevated mortality rates that may result from a range of management practices. These data have also been used in PVAs for Victorian populations to identify key threats to population viability (Todd *et al.* 2007). However, the variability of demographic data between populations is not well understood, and for the majority of populations there are minimal demographic data on which to base management decisions. Therefore, long-term projects are required across the species' range to increase knowledge of population demographics to facilitate management. Some demographic data could be collected in parts of the species' range where live-trapping is implemented to monitor population status. However, in other parts of the species' range where trapping may not be a feasible monitoring option, additional targeted programs will be required to collect the required data. In areas where latrines can be targeted, the use of non-invasive survey methods that allow individuals to be identified, such as genetic analysis of DNA extracted from scats, and camera trapping, may provide alternatives to trapping for collecting demographic data.

**Implementation partners:** Office of Environment & Heritage NSW; Dept. Environment & Heritage Protection QLD; Dept. Environment, Land, Water & Planning VIC; Dept. Primary Industries, Parks, Water & Environment TAS; Environment and Planning Directorate ACT; Recovery Team.

**Priority:** High

### **Objective 3. Reduce the rate of habitat loss and fragmentation on private land.**

**Action 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.

*Performance criterion: Increased protection of Spotted-tailed Quolls and their habitat on private land.*

Widespread clearance of native vegetation for agriculture, plantations and other developments (e.g. dams) is a key threat to Spotted-tailed Quoll populations. State and territory policy and legislation regulate the clearance of native vegetation on both public and private land. Core habitat areas and corridors need to be identified and protected on a landscape scale. To help prevent the further loss and fragmentation of existing Spotted-tailed Quoll habitat on private land, landholders in areas where populations are known to occur and whose properties contain suitable habitat will be encouraged to place covenants on their land to prevent future clearing. Landholders will also be encouraged to manage their land in a way that is compatible with Spotted-tailed Quoll conservation (e.g. the retention of large hollow-bearing trees and logs, feral animal management, pet animal management).

**Implementation partners:** Project officer, Office of Environment & Heritage NSW; Dept. Environment & Heritage Protection QLD; Dept. Environment, Land, Water & Planning VIC; Dept. Primary Industries, Parks, Water & Environment TAS; Environment and Planning Directorate ACT, non-government conservation agencies, catchment management authorities, natural resource management regional bodies.

**Priority:** High

**Action 3.2** Maintain and restore habitat corridors on unprotected freehold land.

*Performance criterion: Efforts to increase habitat connectivity commenced in four areas identified as important for the establishment of corridors.*

Spotted-tailed Quolls are known to move through existing remnant vegetation corridors. Consequently, protecting and enhancing existing corridors, or creating new corridors between existing habitat patches, will benefit dispersing individuals. Existing corridors will be identified and voluntary conservation agreements sought with landholders to retain, manage and/or rehabilitate habitat corridors in a manner that is compatible with Spotted-tailed Quoll conservation. In areas identified as important for the establishment of viable habitat corridors, where possible, landholders will be offered incentives such as fencing assistance to establish and maintain corridors. In some cases, corridor protection and revegetation programs may be conducted in association with established agency and community group revegetation programs. Important corridors need to be identified as significant native vegetation in appropriate regional planning instruments.

**Implementation partners:** Office of Environment & Heritage NSW; Dept. Environment & Heritage Protection QLD; Dept. Environment, Land, Water & Planning VIC; Dept. Primary Industries, Parks, Water & Environment TAS; Environment and Planning Directorate ACT, Tasmanian Forest Practices Authority, non-government conservation agencies, local government, catchment management authorities, natural resource management groups.

**Priority:** High

**Action 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.

*Performance criterion: Urban development guidelines produced and disseminated to local councils.*

In areas where urban developments are threatening Spotted-tailed Quoll populations or habitat, a list of recommendations should be provided to local councils advising them of measures that can be taken to reduce the impact of such development on the species. Such measures may include the imposition of by-laws to restrict the ranging behaviour of domestic dogs and cats, reductions in road speed limits, and regulations requiring poultry pens and aviaries to be built to comply with recommended 'quoll-proof' designs. Education of the local community regarding the need for such mitigating measures will increase their willingness to adopt such restrictions (Action 11.2).

**Implementation partners:** Project officer, catchment management authorities, natural resource management groups.

**Priority:** High

**Objective 4. Evaluate and manage the risk posed by silvicultural practices.**

Action 4.1 Develop guidelines on minimum habitat requirements that can be used to direct the formation of habitat retention prescriptions or other requirements in commercially harvested forests.

*Performance criterion: Habitat retention guidelines produced.*

Habitat retention guidelines for timber production forests where Spotted-tailed Quolls are known to occur will be developed based on a review of current information on the biology and ecology of Spotted-tailed Quolls, e.g. habitat and area requirements, life history parameters such as seasonality of breeding, and weaning and dispersal of young, and preferred prey. These guidelines will assist forestry planners in revising and/or developing habitat retention prescriptions or other requirements.

**Implementation partners:** Project officer, Office of Environment & Heritage NSW; Dept. Environment & Heritage Protection QLD; Dept. Environment, Land, Water & Planning VIC; Dept. Primary Industries, Parks, Water & Environment TAS; Environment and Planning Directorate ACT, Tasmanian Forest Practices Authority.

**Priority:** High

Action 4.2 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.

*Performance criterion: Habitat to support viable populations of Spotted-tailed Quolls retained in commercially harvested forests.*

Habitat retention prescriptions for Spotted-tailed Quolls currently exist for all commercially harvested forests within the species' range. Scientifically rigorous monitoring programs are required to ensure these prescriptions contribute effectively to the conservation of the species in these forests. Undesirable changes in the demographics and relative abundance of Spotted-tailed Quoll populations detected by monitoring can then be addressed through changes to current prescriptions within an adaptive management framework. Collection of concurrent data on the relative abundance of preferred prey species will provide information on threshold prey densities required to support quoll populations.

**Implementation partners:** Private forestry agencies, Office of Environment & Heritage NSW; Dept. Environment & Heritage Protection QLD; Dept. Environment, Land, Water & Planning VIC; Dept. Primary Industries, Parks, Water & Environment TAS; Environment and Planning Directorate ACT, Tasmanian Forest Practices Authority.

**Priority:** High

Action 4.3 Determine disturbance thresholds of female Spotted-tailed Quolls to refine habitat retention prescriptions or other requirements in harvested areas.

*Performance criterion: Habitat retention prescriptions or other requirements refined through increased understanding of the impact of silvicultural systems on female Spotted-tailed Quolls.*

The level of disturbance Spotted-tailed Quolls, particularly breeding females, are able to tolerate under a range of silvicultural systems, is currently unknown. The persistence of viable Spotted-tailed Quoll populations in some selectively logged forests in NSW and Queensland (Burnett 1993; Belcher 2000; A. Glen pers. comm.) indicates the species exhibits a level of tolerance to some silvicultural practices. Timber harvesting operations within the home ranges of female Spotted-tailed Quolls could reduce the availability of den sites and prey and, depending on the scale and intensity of harvesting, could affect the capacity of female quolls to raise their young. Monitoring programs are required to determine the response of female Spotted-tailed Quolls to timber harvesting operations in areas subject to different scales and intensities of harvesting. The results will be used to develop guidelines outlining minimal impact forestry practices and to refine existing habitat retention prescriptions or other requirements for areas of quoll habitat subject to timber harvesting.

**Implementation partners:** Private forestry agencies, Office of Environment & Heritage NSW; Dept. Environment & Heritage Protection QLD; Dept. Environment, Land, Water & Planning VIC; Dept. Primary Industries, Parks, Water & Environment TAS; Environment and Planning Directorate ACT, Tasmanian Forest Practices Authority.

**Priority:** Medium

**Objective 5. Determine and manage the threat posed by introduced predators (foxes, cats, wild dogs) and of predator control practices on Spotted-tailed Quoll populations.**

Action 5.1 Monitor the abundance of Spotted-tailed Quolls and introduced predators in areas with and without predator control programs.

*Performance criterion: Monitoring programs established to inform predator management in areas occupied by Spotted-tailed Quolls.*

There is some evidence that competitive and predatory interactions are occurring between Spotted-tailed Quolls and foxes, feral cats and wild dogs. However, it is not known if these interactions are having a significant impact at the population level. Broad-scale control programs targeting wild dogs and foxes are undertaken in many areas occupied by Spotted-tailed Quolls. Spotted-tailed Quoll populations are expected to benefit, particularly from reduced fox abundance (Glen & Dickman 2008; Glen *et al.* 2011). However, predator populations interact with each other in a variety of complex ways (see Glen *et al.* 2007; Johnson and VanDerWal 2009) and the removal of one species, as is commonly the practice with control programs, may lead to an increase in co-occurring predators, with potentially undesirable consequences for native species including Spotted-tailed Quolls (Glen & Dickman 2008; Glen *et al.* 2011). Monitoring Spotted-tailed Quoll and introduced predator abundance (or an index of abundance) simultaneously in areas where predator control programs are being implemented, as well as areas without control programs, will provide data on the impact of control programs and introduced predators on Spotted-tailed Quoll populations. These data can then be used to inform ongoing predator control in areas occupied by Spotted-tailed Quolls within an adaptive management framework. Areas where bait delivery methods result in baits being laid on the surface of the ground (e.g. aerial deployment, ground surface deployment) and which are likely to support Spotted-tailed Quolls, should be the priority for monitoring.

**Implementation partners:** Office of Environment & Heritage NSW; Dept. Environment & Heritage Protection QLD; Dept. Environment, Land, Water & Planning VIC; Dept. Primary Industries, Parks, Water & Environment TAS; Environment and Planning Directorate ACT; rural land management agencies.

**Priority:** High

Action 5.2 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.

*Performance criterion: PVA used to inform predator control programs.*

Recent studies investigating the impact of baiting with 1080 to control foxes and wild dogs on the immediate survival of radio-collared Spotted-tailed Quolls found that despite evidence that a number of the radio-collared quolls had eaten poisoned baits, most survived. However, a small number of individuals that consumed poisoned baits died as a direct result (Körtner *et al.* 2003; Körtner & Watson 2005; NRW 2006; Claridge & Mills 2007; Körtner 2007). While these studies provide new insights into the response of Spotted-tailed Quolls to baiting programs in the short-term, the long-term impact on population viability is unknown. The response of populations across the species' range is likely to vary depending on the size and degree of isolation of the quoll population, and the timing, intensity and frequency of the control program. Whether or not baits are buried during control programs is also likely to be an important factor influencing whether Spotted-tailed Quolls consume poisoned baits and die as a result. Population viability modelling is required to help address these questions and guide the implementation of baiting programs across the species' range. Although the reduction of mesopredators, particularly foxes, resulting from control programs is expected to benefit Spotted-tailed Quolls (Glen & Dickman 2008), results of preliminary PVA indicate that even small additional mortalities from 1080 poisoning could have a major effect on the likelihood of persistence of small, fragmented and declining populations. These analyses also highlighted significant gaps in knowledge of the

demographics of Spotted-tailed Quoll populations (Todd *et al.* 2007). PVAs will be greatly facilitated by the collection of site-specific demographic data as outlined in Action 2.4.

**Implementation partners:** Office of Environment & Heritage NSW; Dept. Environment & Heritage Protection QLD; Dept. Environment, Land, Water & Planning VIC; Dept. Primary Industries, Parks, Water & Environment TAS; Environment and Planning Directorate ACT.

**Priority:** Medium

Action 5.3 Assess the potential impact of strychnine use in areas of known or potential Spotted-tailed Quoll habitat.

*Performance criterion: The use of strychnine in areas of Spotted-tailed Quoll habitat determined and restricted if required.*

Strychnine is a highly toxic compound which is subject to strict regulatory controls. Permits for its use can be obtained in Queensland, NSW and South Australia where it may be used to control wild dogs, either in poisoned baits or impregnated into cloth wrapped around soft-jawed traps. Strychnine kills Spotted-tailed Quolls and its use should be restricted in areas where the species may be exposed to this poison. Determining the current extent of use, purpose, and existing controls in areas likely to be occupied by Spotted-tailed Quolls, will inform the level of threat to the species and the requirement for more stringent controls on the use of this poison.

**Implementation partners:** Office of Environment & Heritage NSW; Dept. Environment & Heritage Protection QLD.

**Priority:** High

Action 5.4 Review existing information on alternative poison delivery or biological control systems to identify systems with high target species specificity that could be applied in areas occupied by Spotted-tailed Quolls.

*Performance criterion: Increased knowledge of alternative poison delivery systems that reduce the likelihood of non-target poisoning.*

Alternative poison delivery systems that have a higher level of target species specificity than current bait deployment methods should be investigated. The M-44 ejector, a mechanical device that delivers a dose of powdered toxin into the mouth of an animal as it bites on a trigger mechanism (Busana *et al.* 1998), has been found to effectively deliver a lethal dose of capsules containing 1080 to captive foxes in Victoria. It has been proposed as a potentially more target-specific means of delivery as it is not easily removed and cached by foxes (Marks *et al.* 1999). A multi-dose ejector capable of delivering multiple doses of poison that is sprayed into the mouth of an animal as it bites on the device is currently in development. This device has been specifically designed to target foxes (M. Lindeman pers. comm.). A method of poison delivery that targets cats is also being investigated (M. Johnston pers. comm.).

**Implementation partners:** Project officer, Office of Environment & Heritage NSW; Dept. Environment & Heritage Protection QLD; Dept. Environment, Land, Water & Planning VIC; Dept. Primary Industries, Parks, Water & Environment TAS; Environment and Planning Directorate ACT.

**Priority:** Low

## **Objective 6. Determine and manage the impact of fire regimes on Spotted-tailed Quoll populations.**

Action 6.1 Incorporate the need for protection of rocky outcrops and riparian zones into fire planning processes within areas of known Spotted-tailed Quoll habitat.

*Performance criterion: Critical habitat features for Spotted-tailed Quolls protected during planned burns.*

Rocky outcrops and large logs are known to provide den sites for Spotted-tailed Quolls (Belcher & Darrant 2006a; Glen & Dickman 2006a), while fallen timber facilitates movement through the forest (Glen & Dickman 2006a). Riparian zones can provide high quality habitat for the species' preferred medium-sized mammalian prey (Belcher 1995; Belcher & Darrant 2006b; Glen & Dickman 2006b). Protection of these habitat features within known Spotted-tailed Quoll habitat is likely to reduce the impact of planned burns on Spotted-tailed Quolls and their prey.



**Implementation partners:** Office of Environment & Heritage NSW; Dept. Environment & Heritage Protection QLD; Dept. Environment, Land, Water & Planning VIC; Dept. Primary Industries, Parks, Water & Environment TAS; Environment and Planning Directorate ACT.

**Priority:** High

Action 6.2 Investigate the impact of bushfires and planned burns on Spotted-tailed Quoll populations and develop prescriptions for planned burns in areas of quoll habitat.

*Performance criterion: Monitoring programs established to inform fire management in Spotted-tailed Quoll habitat.*

To improve current fire prescriptions, monitoring programs are required to determine the impact of fire on Spotted-tailed Quoll populations in areas under varying fire regimes. Factors that may influence the ability of quolls to survive the immediate and longer-term impact of bushfires, and increase their resilience to planned burns, such as the scale and intensity of the burn, the presence of various refugia, the availability of prey resources, the abundance of other predators, and the likelihood of recruitment from adjacent areas, should also be assessed. This information should be used to develop prescriptions to guide planned burning in areas of Spotted-tailed Quoll habitat. Until this information becomes available, the need to protect rocky outcrops and riparian habitat should be incorporated in fire planning processes in areas known to support Spotted-tailed Quolls (Action 6.1).

**Implementation partners:** Office of Environment & Heritage NSW; Dept. Environment & Heritage Protection QLD; Dept. Environment, Land, Water & Planning VIC; Dept. Primary Industries, Parks, Water & Environment TAS; Environment and Planning Directorate ACT.

**Priority:** Medium

#### **Objective 7. Reduce deliberate killings of Spotted-tailed Quolls.**

Action 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.

*Performance criterion: 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.*

To reduce Spotted-tailed Quoll predation on domestic poultry and the potential for negative quoll/human interactions, a brochure illustrating 'quoll-proof' poultry runs will be produced and distributed to landholders. Such poultry runs will also be beneficial in reducing predation by foxes, goannas, goshawks and pythons. Educational material (Action 11.2) will also be provided to these landholders to increase knowledge of and empathy for the Spotted-tailed Quoll.

**Implementation partners:** Project officer, Office of Environment & Heritage NSW; Dept. Environment & Heritage Protection QLD; Dept. Environment, Land, Water & Planning VIC; Dept. Primary Industries, Parks, Water & Environment TAS; Environment and Planning Directorate ACT, non-government conservation agencies, natural resource management groups, catchment management authorities.

**Priority:** High

#### **Objective 8. Reduce the frequency of Spotted-tailed Quoll road mortality.**

Action 8.1 Identify sections of road where Spotted-tailed Quolls are frequently killed.

*Performance criterion: Spotted-tailed Quoll road-kill hotspots identified.*

Wildlife atlas records and data collected by government road authorities, other government agencies and the public will be used to identify sections of road where Spotted-tailed Quolls are frequently killed.

**Implementation partners:** Office of Environment & Heritage NSW; Dept. Environment & Heritage Protection QLD; Dept. Environment, Land, Water & Planning VIC; Dept. Primary Industries, Parks, Water & Environment TAS; Environment and Planning Directorate ACT.

**Priority:** High

**Action 8.2** Review existing information, and monitor existing mitigation measures to identify the most effective mitigation actions for reducing Spotted-tailed Quoll road deaths.

*Performance criterion: Mitigating measures for reducing Spotted-tailed Quoll road deaths identified.*

A review of mitigating techniques (e.g. speed limit signs, rumble bars, chicanes, underpasses) from around Australia and overseas will be undertaken to determine which technique/s represent the most cost-effective and feasible solution for reducing Spotted-tailed Quoll road deaths.

**Implementation partners:** Project officer, Office of Environment & Heritage NSW; Dept. Environment & Heritage Protection QLD; Dept. Environment, Land, Water & Planning VIC; Dept. Primary Industries, Parks, Water & Environment TAS; Environment and Planning Directorate ACT.

**Priority:** High

**Action 8.3** Implement mitigation measures at road-kill hotspots.

*Performance criterion: Spotted-tailed Quoll road deaths reduced at road-kill hotspots.*

Mitigating solutions (Action 8.2) should be incorporated into Spotted-tailed Quoll road-kill hotspots (Action 8.1), and made an approval requirement for the construction of new roads in known Spotted-tailed Quoll habitat. Road mortality of Spotted-tailed Quolls, and other native scavengers (e.g. Tasmanian Devils, Wedge-tailed Eagles, goannas and other quoll species), can be further reduced if road authorities and local councils are encouraged to obtain permits that allow them to remove wildlife carcasses from roads. On an upgraded road in north-west Tasmania in core Spotted-tailed Quoll habitat, where speed reduction and underpasses were not feasible options, the removal of roadside vegetation and maintenance of grass-free verges was implemented in addition to carcass collection to reduce Spotted-tailed Quoll road-kills (N. Mooney pers. comm. to M. Jones).

**Implementation partners:** Project officer, operational groups, state and territory transport and planning authorities, local councils.

**Priority:** High

### **Objective 9. Assess the threat Cane Toads pose to Spotted-tailed Quolls and implement threat abatement actions if necessary**

**Action 9.1** Map the current distribution of Spotted-tailed Quolls and Cane Toads to identify areas of overlap, and determine factors that affect the survival of quolls in these areas.

*Performance criterion: Increased understanding of factors that facilitate the persistence of Spotted-tailed Quolls in areas where they co-occur with Cane Toads.*

The identification of priority native species at risk from the impact of cane toads is a primary objective of the Cane Toad Threat Abatement Plan (SEWPAC 2011). The threat that Cane Toads pose to Spotted-tailed Quoll populations has yet to be established. To assess the potential risk to the species, populations within the zone of overlap with Cane Toads should be identified and studies instigated to determine factors that enable quolls to persist in areas occupied by toads. These studies should consider toad densities, the health and survival of quolls, and the habitat preferences of both species.

**Implementation partners:** Office of Environment & Heritage NSW; Dept. Environment & Heritage Protection QLD; Project officer.

**Priority:** High

**Action 9.2** Monitor the survival of Spotted-tailed Quolls in areas newly colonised by Cane Toads.

*Performance criterion: Increased understanding of the threat posed by Cane Toads to Spotted-tailed Quolls.*

To assess the impact of Cane Toads, monitoring must commence prior to the arrival of the toads then continue during the invasion period for at least a year (M. Oakwood pers. comm.).

The use of radio-telemetry to monitor survival would allow dead Spotted-tailed Quolls to be recovered and the cause of death to be determined. Quoll deaths caused by Cane Toads can usually be established from the presence of distinctive external signs (Oakwood 2004). Monitoring of quoll populations in subsequent years would allow population trends in the longer term to be determined.

**Implementation partners:** Office of Environment & Heritage NSW; Dept. Environment & Heritage Protection QLD.

**Priority:** Medium

Action 9.3 If, based on the investigations in 9.1 and 9.2, it is considered that Cane Toads are a threat to quoll populations, identify and implement appropriate threat abatement actions.

*Performance criterion: Threat abatement actions identified and implemented in areas where Cane Toads threaten Spotted-tailed Quoll populations.*

If Cane Toads are confirmed as being a threat to Spotted-tailed Quoll populations, the recovery team, or relevant operational group/s, should liaise and coordinate threat abatement actions and research with other organisations that are also working to control the impact of Cane Toads. Spotted-tailed Quoll populations exposed to additional threatening processes that may exacerbate the impact of Cane Toads (particularly urban development) should be monitored. This will allow 'at risk' populations to be identified and threat abatement efforts to be prioritised.

**Implementation partners:** Office of Environment & Heritage NSW; Dept. Environment & Heritage Protection QLD.

**Priority:** Medium

#### **Objective 10. Determine the likely impact of climate change on Spotted-tailed Quoll populations.**

Action 10.1 Identify and map populations considered to be 'at risk' from habitat alterations resulting from climate change.

*Recovery Criterion: Populations at risk from climate change are identified and mapped.*

Habitat modelling suggests that highland rainforest, which is habitat for the northern sub-species of Spotted-tailed Quoll, will decrease by 50% as a consequence of a 1°C increase in temperature. Spotted-tailed Quoll populations that will be potentially threatened by such climatic changes should be identified and mapped.

**Implementation partners:** Office of Environment & Heritage NSW; Dept. Environment & Heritage Protection QLD; Dept. Environment, Land, Water & Planning VIC; Dept. Primary Industries, Parks, Water & Environment TAS; Environment and Planning Directorate ACT.

**Priority:** Low

Action 10.2 Include at least two identified 'at risk' populations in long-term monitoring programs (Action 1.3).

*Recovery Criterion: Population trends determined for two 'at risk' populations identified by action 10.1.*

A sample of 'at risk' populations (at least two) should be monitored annually (some or all of these should be incorporated into the long-term monitoring program described in Action 1.3) to allow risk assessments to be updated and additional recovery actions initiated if necessary. The retention and protection of potential habitat adjacent to existing habitat will be necessary to achieve the long-term protection of Spotted-tailed Quoll populations. The prioritisation of potential habitat for protection should be directed by habitat modelling simulations.

**Implementation partners:** Office of Environment & Heritage NSW; Dept. Environment & Heritage Protection QLD; Dept. Environment, Land, Water & Planning VIC; Dept. Primary Industries, Parks, Water & Environment TAS; Environment and Planning Directorate ACT.

**Priority:** Low

**Objective 11. Increase community awareness of the Spotted-tailed Quoll and involvement in the Recovery Program.**

Action 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.

*Recovery Criterion: Public education strategy developed.*

The public's general ignorance of Spotted-tailed Quolls and their basic biology has been documented in southern Queensland (Watt 1993), and the widespread deliberate killing of the species in this region and elsewhere suggests there is little empathy for it, at least in some sections of the community. A number of threats to the species, namely deliberate killing, road mortality and urban development, can be mitigated to a significant extent with the support of the public. For this reason a public education strategy is considered a high priority. Determining the target audience and the most appropriate avenues for raising public awareness are key steps in the development of the strategy.

**Implementation partners:** Office of Environment & Heritage NSW; Dept. Environment & Heritage Protection QLD; Dept. Environment, Land, Water & Planning VIC; Dept. Primary Industries, Parks, Water & Environment TAS; Environment and Planning Directorate ACT; non-government conservation agencies; project officer.

**Priority:** High

Action 11.2 Prepare education resources and distribute these to the identified target audience.

*Recovery Criterion: Education resources distributed to target audience to increase public awareness.*

Educational resources such as brochures, 'Info sheets' and 'Fact sheets' will be reviewed, compiled and distributed to priority audiences to increase knowledge of and empathy for the Spotted-tailed Quoll and its conservation plight.

**Implementation partners:** Project officer.

**Priority:** High

Action 11.3 Involve the community in survey and monitoring efforts for the species.

*Recovery Criterion: Community participation in Spotted-tailed Quoll conservation increased.*

By involving the community in conservation management and research actions it is anticipated that they will develop a level of 'ownership' of the species that will encourage their ongoing support for the Recovery Program.

**Implementation partners:** Office of Environment & Heritage NSW; Dept. Environment & Heritage Protection QLD; Dept. Environment, Land, Water & Planning VIC; Dept. Primary Industries, Parks, Water & Environment TAS; Environment and Planning Directorate ACT; non-government conservation agencies; project officer.

**Priority:** Medium

Action 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.

*Recovery Criterion: Public awareness of the Spotted-tailed Quoll increased through provision of information at captive facilities.*

Captive colonies of Spotted-tailed Quolls maintained in facilities with high levels of public visitation can play an important role in raising public awareness of the Spotted-tailed Quoll and its conservation plight.

**Implementation partners:** Captive management institutions, project officer.

**Priority:** Low

**Table 2. Implementation Costs**

The estimated cost of implementing the Recovery Plan is \$5.077 million over five years.

Obj	Action	Priority	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Total	
<b>1</b>	<b>Distribution &amp; status</b>								
1.1	Survey protocol	High	20					<b>20</b>	
1.2	Survey, map distribution	High	165	165	165			<b>495</b>	
1.3	Monitoring	High	20	195	195	160	160	<b>730</b>	
<b>2</b>	<b>Biology &amp; ecology</b>								
2.1	Data collection protocol	Medium	10					<b>10</b>	
2.2	Genetic diversity	Medium	10	10	10	10	10	<b>50</b>	
2.3	Genetic analyses	Low					5	<b>5</b>	
2.4	Demographic data	High	125	110	110	110	130	<b>585</b>	
<b>3</b>	<b>Habitat loss</b>								
3.1	Habitat protection	High	30		30			<b>60</b>	
3.2	Habitat connectivity	High	30		30			<b>60</b>	
3.3	Urban development guidelines	High	20	20	20			<b>60</b>	
<b>4</b>	<b>Timber harvesting</b>								
4.1	Habitat retention guidelines	High	10					<b>10</b>	
4.2	Monitoring habitat retention	High	190	170	170	170	170	<b>870</b>	
4.3	Disturbance thresholds	Medium		135	135	135	25	<b>430</b>	
<b>5</b>	<b>Predation &amp; competition</b>								
5.1	Predator management	High	170	170	170	25		<b>535</b>	
5.2	PVA	Medium				20	20	<b>40</b>	
5.3	Strychnine impact	High	15					<b>15</b>	
5.4	Alternative poison delivery	Low			10			<b>10</b>	
<b>6</b>	<b>Fire regimes</b>								
6.1	Fire prescriptions	High	25					<b>25</b>	
6.2	Fire impact	Medium	125	105	105	25		<b>360</b>	
<b>7</b>	<b>Deliberate killing</b>								
7.1	Landholder information	High	10	30	30			<b>70</b>	
<b>8</b>	<b>Road mortality</b>								
8.1	Road mortality hotspots	High	15					<b>15</b>	
8.2	Mitigation evaluation	High	15	15				<b>30</b>	
8.3	Mitigation implementation	High		30	30			<b>60</b>	
<b>9</b>	<b>Cane Toad risk</b>								
9.1	Cane Toad risk evaluation	High	70	70	70			<b>210</b>	
9.2	Monitoring	Medium	60	25	25	25	25	<b>160</b>	
9.3	Threat abatement	Medium		10	10			<b>20</b>	
<b>10</b>	<b>Climate change</b>								
10.1	Climate change risk evaluation	Low	7					<b>7</b>	
10.2	Monitoring	Low		Funded under Action 1.3					
<b>11</b>	<b>Community involvement</b>								
11.1	Communication strategy	High	25					<b>25</b>	
11.2	Educational resources	High	15	5	5	5	5	<b>35</b>	
11.3	Community involvement	Medium	12	12	12	12	12	<b>60</b>	
11.4	Information plaques	Low	15					<b>15</b>	
<b>Totals</b>			<b>1,209</b>	<b>1,277</b>	<b>1,332</b>	<b>697</b>	<b>562</b>	<b>5,077</b>	

**Table 3. Recovery Objectives, Performance Criteria and Actions – Summary**

Objective	Performance Criteria	Actions
<p>1. Determine the distribution and status of Spotted-tailed Quoll populations throughout the range, and identify key threats and implement threat abatement management practices.</p>	<p>Standardised survey and monitoring protocols identified for use throughout the species' range.</p>	<p>1.1 Develop targeted survey techniques and monitoring protocols.</p>
	<p>An increase in knowledge of the current distribution and status of populations.</p>	<p>1.2 Undertake field surveys and mapping in areas where the distribution and status of populations are poorly known.</p>
	<p>Factors influencing distribution and abundance identified and management actions implemented to mitigate threats at key sites throughout the range.</p>	<p>1.3 Develop and implement a program to monitor Spotted-tailed Quoll population status, identify threats and implement management actions at representative sites throughout the species' range.</p>
<p>2. Investigate key aspects of the biology and ecology of the Spotted-tailed Quoll to acquire targeted information to aid recovery.</p>	<p>Standard data collection protocol developed for live-trapping studies.</p>	<p>2.1 Develop a standard data collection protocol for live-trapping studies.</p>
	<p>Genetic management units identified.</p>	<p>2.2 Conduct genetic analyses to determine genetic variation between populations and identify appropriate genetic management units.</p>
	<p>Genetic analysis of captive animals undertaken and genetic profiles documented and used to inform breeding programs.</p>	<p>2.3 Undertake genetic analysis of all captive animals and ensure their genetic profile is adequately documented to facilitate the maintenance of a genetically representative and diverse captive population.</p>
	<p>Demographic data collected for at least three Spotted-tailed populations for use in PVA to facilitate management.</p>	<p>2.4 Investigate population demographics, particularly age-specific survival rates, juvenile dispersal and reproductive life span, to facilitate population viability modelling and conservation management.</p>
<p>3. Reduce the rate of habitat loss and fragmentation on private land.</p>	<p>Increased protection of Spotted-tailed Quolls and their habitat on private land.</p>	<p>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.</p>
	<p>Efforts to increase habitat connectivity commenced in four areas identified as important for the establishment of corridors.</p>	<p>3.2 Maintain and restore habitat corridors on unprotected freehold land.</p>
	<p>Urban development guidelines produced and disseminated to local councils.</p>	<p>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.</p>

<b>Objective</b>	<b>Performance Criteria</b>	<b>Actions</b>
4. Evaluate and manage the risk posed by silvicultural practices.	Habitat retention guidelines produced.	4.1 Develop guidelines on minimum habitat requirements that can be used to direct the formation of habitat retention prescriptions or other requirements in commercially harvested forests.
	Habitat to support viable populations of Spotted-tailed Quolls retained in commercially harvested forests.	4.2 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.
	Habitat retention prescriptions or other requirements refined through increased understanding of the impact of silvicultural systems on female Spotted-tailed Quolls.	4.3 Determine disturbance thresholds of female Spotted-tailed Quolls to refine habitat retention prescriptions or other requirements in harvested areas.
5. Determine and manage the threat posed by introduced predators (foxes, cats, wild dogs) and of predator control practices on Spotted-tailed Quoll populations.	Monitoring programs established to inform predator management in areas occupied by Spotted-tailed Quolls.	5.1 Monitor the abundance of Spotted-tailed Quolls and introduced predators in areas with and without predator control programs.
	PVA used to inform predator control programs.	5.2 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.
	The use of strychnine in areas of Spotted-tailed Quoll habitat determined and restricted if required.	5.3 Assess the potential impact of strychnine use in areas of known or potential Spotted-tailed Quoll habitat.
	Increased knowledge of alternative poison delivery systems that reduce the likelihood of non-target poisoning.	5.4 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.	Critical habitat features for Spotted-tailed Quolls protected during planned burns.	6.1 Incorporate the need for protection of rocky outcrops and riparian zones into fire planning processes within areas of known Spotted-tailed Quoll habitat.
	Monitoring programs established to inform fire management in Spotted-tailed Quoll habitat.	6.2 Investigate the impact of bushfires 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.

Objective	Performance Criteria	Actions
8. Reduce the frequency of Spotted-tailed Quoll road mortality.	Spotted-tailed Quoll road-kill hotspots identified.	8.1 Identify sections of road where Spotted-tailed Quolls are frequently killed.
	Mitigating measures for reducing Spotted-tailed Quoll road deaths identified.	8.2 Review existing information, and monitor existing mitigation measures to identify the most effective mitigation actions for reducing road deaths.
	Spotted-tailed Quoll road deaths reduced at road-kill hotspots.	8.3 Implement mitigation measures at road-kill hotspots.
9. Assess the threat Cane Toads pose to Spotted-tailed Quolls and implement threat abatement actions if necessary.	Increased understanding of factors that facilitate the persistence of Spotted-tailed Quolls in areas where they co-occur with Cane Toads.	9.1 Map the current distribution of Spotted-tailed Quolls and Cane Toads to identify areas of overlap, and determine factors that affect the survival of quolls in these areas.
	Increased understanding of the threat posed by Cane Toads to Spotted-tailed Quolls.	9.2 Monitor the survival of Spotted-tailed Quolls in areas newly colonised by Cane Toads.
	Threat abatement actions identified and implemented in areas where Cane Toads threaten Spotted-tailed Quoll populations.	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.
10. Determine the likely impact of climate change on Spotted-tailed Quoll populations.	Populations at risk from climate change are identified and mapped	10.1 Identify and map populations considered to be 'at risk' from habitat alterations resulting from climate change.
	Population trends determined for two 'at risk' populations identified by action 10.1.	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.	Public education strategy developed.	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.
	Education resources distributed to target audience to increase public awareness.	11.2 Compile education resources and distribute these to the identified target audience.
	Community participation in Spotted-tailed Quoll conservation increased.	11.3 Involve the community in survey and monitoring efforts for the species.
	Public awareness of the Spotted-tailed Quoll increased through provision of information at captive facilities.	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.



## **Affected Interests**

A wide range of organisations has legislative responsibilities for the protection of the Spotted-tailed Quoll, and will be involved in all stages of this Recovery Plan. At a national level, the taxon is listed as threatened under the EPBC Act, administered by the Australian Government Department of Sustainability, Environment, Water, Population and Communities. Any action that will have, or is likely to have, a significant impact on a taxon listed under this legislation will trigger the assessment and approval provisions of the EPBC Act, necessitating approval for that action from the Commonwealth Environment Minister.

The management of the species at a state level is the legislative responsibility of the various state and territory agencies that oversee biodiversity conservation. Because the species is distributed across private and public land under various management regimes, a wide range of organisations also have responsibility for habitat protection and management. The primary agencies/organisations and their relevant governing legislation with respect to Spotted-tailed Quoll management and conservation are provided in Table 4.

Where the Spotted-tailed Quoll occurs on freehold land the EPBC Act outlines the responsibility of private landholders to ensure that development on their properties does not impact on the species. Any significant developments commencing since the inception of the EPBC Act must be referred to the Commonwealth Environment Minister for assessment and approval. Private landowners can facilitate monitoring and recovery actions for the Spotted-tailed Quoll by permitting access to habitat on their land, consulting with agencies and individuals involved in these activities, participating in survey and monitoring initiatives and ensuring that their own activities do not negatively impact the species or its habitat on or near their properties.

In addition to the organisations identified in Table 4, the threat abatement actions outlined in this Recovery Plan will require the involvement of additional agencies and individuals. The protection of Spotted-tailed Quoll populations and habitat with respect to the threats posed by habitat clearance, fire regimes, fragmentation and the encroachment of urban development into bushland areas will require input from state and territory government planning authorities, local councils, rural fire authorities, and consultancies involved in conducting environmental impact assessments. Mitigation actions required to reduce the incidence of Spotted-tailed Quoll road mortality will involve state and territory road transport authorities, local councils, and local government planning authorities. Landholder cooperation is required to modify poultry sheds to quoll-proof designs, which will help prevent direct killings of Spotted-tailed Quolls on private land. Research actions will be undertaken by universities, government research institutes and private consultancies as well as conservation and state forest agencies.

**Table 4.** Agencies with an interest in the conservation of the Spotted-tailed Quoll

State	Agency/Organisation
QLD	Department of Environment and Heritage Protection Department of National Parks, Recreation, Sport and Racing Department of State Development, Infrastructure and Planning Department of Agriculture, Fisheries and Forestry Department of Natural Resources and Mines Department of Transport and Main Roads Natural resource management regional bodies Quoll Seekers Network
NSW	Office of Environment and Heritage Department of Planning and Infrastructure Department of Primary Industries Catchment management authorities Roads and Maritime Services Forestry Corporation of New South Wales Livestock Health and Pest Authority
ACT	Environment and Sustainable Development Directorate Economic Development Directorate Territory and Municipal Services
VIC	Department of Environment, Land, Water and Planning Parks Victoria Catchment Management Authorities Roads Corporation Victoria VicForests
TAS	Department of Primary Industries, Parks, Water and Environment Department of Economic Development, Tourism and the Arts Forestry Tasmania Private Forests Tasmania Natural Resource Management Regions Department of Infrastructure, Energy and Resources Tasmanian Planning Commission
SA	Department for Environment Water and Natural Resources Natural resource management boards
National	Department of Sustainability, Environment, Water, Population and Communities

### **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 actively encouraged 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 deliberate killing 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 5.1–5.4) and road-kill mitigation measures (Action 8.3).

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 5.1). 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 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**

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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, may be detrimental to the conservation of the species. In particular, any further clearance or fragmentation of habitat of important populations 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 4.3) 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 of important populations 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 deliberate killing. 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 2004b). 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 broad-scale 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 2004b). 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 2004b).

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