Advice to the Minister for Environment Protection, Heritage and the Arts from the Threatened Species Scientific Committee (the Committee) on Amendment to the list of Threatened Species under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)

1. Name

Phascolarctos cinereus

The species is commonly known as the koala. It is the only species in the Family Phascolarctidae.

2. Reason for Conservation Assessment by the Committee

This advice follows assessment of information provided by the Committee nomination to list the koala. The Threatened Species Scientific Committee prepared the nomination and conducted the assessment at the request of the Minister.

This is the Committee's second consideration of the species under the EPBC Act. The species was also considered under the previous Act.

3. Summary of Conclusion

The Committee judges that the species **is not** eligible for listing on the EPBC Act list of threatened species at this time.

4. Taxonomy

The species is conventionally accepted as *Phascolarctos cinereus* (Goldfuss, 1817). It is commonly known as the koala.

Three subspecies of koala have been described: *Phascolarctos cinereus adustus* (Thomas 1923) (Queensland), *P. c. cinereus* (Goldfuss 1817 in (Iredale and Troughton 1934) (New South Wales) and *P.c. victor* (Troughton 1935) (Victoria). These are currently recognised by the Australian Biological Resources Study however their validity has been questioned by genetic and morphological anlayses (see discussion at 7.2).

5. Description

The koala is a tree-dwelling, medium-sized marsupial with a stocky body, large rounded ears, sharp claws and variable but predominantly grey-coloured fur. Males generally are larger than females and there is a gradient in body weight from north to south across their range, with larger individuals in the south and smaller individuals in the north. The average weight of males is 6.5 kg in Queensland, compared with 12 kg in Victoria. Koalas in the north tend to have shorter, silver-grey fur, whereas those in the south have longer, thicker, brown-grey fur (Martin and Handasyde 1999).

6. National Context

The koala is endemic to Australia, and is widespread in coastal and inland areas from north-eastern Queensland to Eyre Peninsula in South Australia (Figure 1) . The range extends over 22° of latitude and 18° of longitude, encompassing more than one million square kilometres (Martin and Handasyde 1999). The koala's distribution is not continuous across this range and it occurs in a number of populations that are separated by cleared land or unsuitable habitat (Martin and Handasyde 1999; NSW DECC 2008).

6.1 Natural Range

The natural range of the koala, which can be inferred from the estimated distribution of the species prior to European settlement in Australia, extends from north-eastern Queensland to the south-east corner of South Australia (ANZECC 1998). This is similar to the current range.

As a consequence of translocations, several koala populations occur outside the species' natural range. These include the Kangaroo Island, Eyre Peninsula, Riverland and Adelaide Hills populations in South Australia. As there are no records of natural occurrences on any Victorian islands (ANZECC 1998), the koala populations on Phillip Island, French Island, Snake Island and Raymond Island in Victoria occur outside the species' natural range (Menkhorst 2008). Similarly, there are introduced koala populations on several islands off the Queensland coast, including Brampton, St. Bees, and Magnetic Islands (Melzer et al. 2000), which could be considered outside the species' natural range. Populations on Newry and Rabbit Islands were believed to be introduced, but recent anecdotal evidence suggests that they may be natural (Lee submitted 2009; Ellis 2010 personal communication).

Not all populations that have wholly or partly originated from translocations occur outside the species' natural range. There are several re-introduced populations, in the Australian Capital Territory, mainland Victoria and the south-east of South Australia, which occur within the koala's natural range (Natural Resource Management Ministerial Council 2010).

6.2 Distribution in the States and Territories

6.2.1 Queensland

Koala populations are scattered throughout Queensland (Queensland EPA 2006), in moist forests along the coast, subhumid woodlands in southern and central Queensland, and in some eucalypt woodlands along watercourses in the semiarid environments of the western part of the state (Melzer et al. 2000). Koalas have also been found to occur in non-riverine communities in semiarid areas (Sullivan et al. 2003a). Koalas also occur on islands off the Queensland coast: populations on St. Bees and Magnetic Islands were introduced, whereas the populations on North Stradbroke, Newry and Rabbit Islands may be natural (Melzer et al. 2000; Lee submitted 2009; Ellis 2010 personal communication).

Biogeographic regions of Queensland where koalas have been recorded include the Einasleigh Uplands, Wet Tropics, Desert Uplands, Central Mackay Coast, Mitchell Grass Downs, Mulga Lands, Brigalow Belt, South Eastern Queensland and Channel Country (Patterson 1996). In addition, koalas are present in the northern parts of several biogeographic regions that extend into New South Wales.

The greatest density of koalas in the state occurs in south-east Queensland, and lower densities occur through central, and western areas (Queensland EPA 2006). For example, population densities range from moderately high in south-east Queensland and some parts of central Queensland (e.g. 1-3 koalas per hectare) to low in other parts of central Queensland (0.01 koalas per hectare) (Melzer et al. 2000 and references therein).

6.2.2 New South Wales

In New South Wales, koalas inhabit a range of forest and woodland communities, including coastal forests, woodlands on the tablelands and western slopes, and woodland communities along watercourses in the western plains (NSW DECC 2008). Many of these areas have no current population estimates available.

Koalas mainly occur on the Central and North Coasts, although significant populations also exist on the Western Slopes and Plains, such as in the Pilliga region and Gunnedah and Walgett local government areas. Koalas are known from a number of sites on the Central and Southern Tablelands and there are also records from the Northern Tablelands. Koalas occur in sparse, and possibly disjunct, populations on the South Coast (Jurskis and Potter 1997; NSW DECC 2008; Allen et al. 2009).

Population densities range from high in parts of the NSW North Coast (e.g. 3 koalas per hectare in an artificially planted reserve at Tucki Tucki (Gall 1980)) to very low (0.006 koalas per hectare (Jurskis and Potter 1997)) near Eden on the South Coast.

6.2.3 Australian Capital Territory

In the Australian Capital Territory, it is thought that there may be currently relatively low density populations of koalas through the Tidbinbilla and Brindabella Ranges, around Bushfold, and in Orroral Valley, Namadgi National Park (Fletcher 2009 personal communication).

There have been several introductions of koalas from Victoria into the ACT between 1939 and the present. It is likely that the current koala population in the ACT is derived mainly from these deliberate introductions, although it is possible that some koalas originate from surviving local populations (Fletcher 2009 personal communication).

6.2.4 Victoria

In Victoria, the koala population was reduced to extremely low numbers by the 1920s, but a re-introduction program over 75 years has resulted in koalas occupying most of the suitable habitat available in the state (Menkhorst 2004). Koalas are widespread in the low altitude forests and woodlands across central and southern mainland Victoria, and also occur on four islands (Raymond, Snake, French and Phillip) (Menkhorst 2004, 2008). Koalas are largely absent from the arid woodlands in the north-west and the high altitude areas of the north-east (Martin and Handasyde 1999).

In Victoria, large regional koala populations occur in the Strathbogie Ranges, Cape Otway, South Gippsland (including the Strzelecki Ranges), forests of the Naracoorte Coast Plain Bioregion, forests and woodlands on Mt Eccles lava flow (between Mt Eccles and Tyrendarra) and the Victorian Midlands Bioregion.

In Victorian forests and woodlands, the population density of koalas is generally less than one koala per hectare (Menkhorst 2004). However, there are several sites where koalas can be at greater densities, including the Strathbogie Ranges, Cape Otway, Mt Eccles National Park, Warrandyte State Park, French Island and Raymond Island (Menkhorst 2008). In some areas, the high density of koalas is putting unsustainable browsing pressure on tree species (Martin 1985a; McLean 2003). These areas include Mt Eccles National Park, Snake Island, Raymond Island and parts of the Otway Ranges (Menkhorst 2008). Some of these populations are subject to population management programs.

6.2.5 South Australia

The koala was presumed extinct in South Australia in 1924 (Wood Jones 1924), but has subsequently been introduced to five locations in the state, including Kangaroo Island, the Riverland, Eyre Peninsula, Adelaide Hills and the South East which was the only area from which they had previously been recorded (Melzer et al. 2000).

Koalas were introduced to Kangaroo Island from French Island (Victoria) in the 1920s and it now supports a large population of koalas, which is putting unsustainable browsing pressure on preferred food tree species such as manna gum (*Eucalyptus viminalis*) and is subject to a population-control program (Masters et al. 2004). Prior to this program, the population density in some areas exceeded 5.5 koalas per hectare (Masters et al. 2004).

Koalas were translocated from Kangaroo Island to three sites in the Riverland between 1959 and 1965. The current Riverland population is thought to be low in numbers and widely dispersed (Robinson et al. 1989). In 1969, koalas from Kangaroo Island were also translocated to Mikkira on southern Eyre Peninsula, and this population has successfully established and dispersed into adjacent areas (Melzer et al. 2000).

Koalas were introduced to the Mount Lofty Ranges in the 1930s and 1960s from Queensland, Victoria, South Australia (Kangaroo Island and possibly the South East of South Australia and possibly New South Wales. The population has since expanded throughout the Adelaide Hills region (Bryan 1996). A preliminary survey in 2003 indicated that there are areas with high population densities in the Adelaide Hills (2.4 to 8.9 koalas per hectare) (SA Govt 2005).

The koala population in South Australia’s South East was re-introduced from Kangaroo Island. Non-sterilised koalas were introduced prior to 1997 and approximately 3000 sterilised koalas have been introduced since 1997 as part of the Kangaroo Island population-control program (Masters et al. 2004; Duka and Masters 2005).

6.3 Status in Jurisdictions Across Distribution

The koala is found across several jurisdictions and has variable threatened species status as outlined below. It should be noted that the koala has been the subject of a variety of conservation plans, including the *National Koala Conservation Strategy 1998* (ANZEC 1998) and *National Koala Conservation and Management Strategy 2009-14* (Natural Resources Management Ministerial Council 2009). Additionally, it is the subject of a state management strategy in Victoria (DSE 2004), a recovery plan and specific state environmental planning policy in New South Wales (DECC 2008), and a Koala Response Strategy in Queensland that includes a south east Queensland koala conservation state planning policy, a net gain koala habitat offsets policy and $45.5 M for net expansion of koala habitat (DERM 2010).

Status

- Queensland - *vulnerable* throughout the South Eastern Queensland bioregion, and 'least concern' (common) elsewhere in the state under the *Nature Conservation Act 1992*.
- New South Wales - *vulnerable* under the *Threatened Species Conservation Act 1995* Two populations are listed as *endangered*; one in the Hawks Nest and Tea Gardens area of Great Lakes local government area, and one in the Pittwater area of Warringah local government area. A nomination for the population occupying the coastal sub-catchments between Dignams Creek and Wapengo Lagoon near Bega in south-eastern New South Wales was rejected on 14 December 2007.
- Victoria - listed as Other Protected Wildlife under the *Wildlife Act 1975*. Not listed as threatened under the *Victorian Flora and Fauna Guarantee Act 1988.*
- South Australia - protected under the *National Parks and Wildlife Act 1972* but not listed in any rare or threatened category.
- International - listed as 'of least concern' on the 2010 IUCN Red List of Threatened Species.
- Listed as threatened on the US *Endangered Species Act 1973.*

7. Relevant Biology/Ecology

7.1 Life History

Female koalas can potentially produce up to one offspring each year, with births occurring between October and May but averages tend to be lower, ranging from 0.3-0.8 per year (McLean 2003). The newly-born koala lives in its mother's pouch for 6-8 months and after leaving the pouch remains dependent on the mother, riding on its back. Young koalas are independent from 12 months of age. The generation length of koalas was estimated to be 6-8 years by Phillips (2000). Additional data from Phillips for other north eastern New South Wales sites, Pilliga and south east Queensland continues to support a figure of approximately 6 years (Phillips 2009 personal communication). Generation times from Victorian populations ranged from 4.5 years (Snake Island) to 6.0 years (Framlingham, French Island) (McLean 2010 personal communication). Population growth rates estimated for koalas range from doubling times of 3.2 in Chlamydia free, high quality habitat on French Island to 20 years (Phillips 2000; McLean 2003).

Longevity in the wild is more than 15 years for females and more than 12 years for males (Martin and Handasyde 1999). Mortality rates per annum at two sites in Queensland (Springsure and Oakey) were estimated to be: subadult females 17% and 16% for Springsure and Oakey respectively, adult females 9.2%/8.5%, subadult males 23%/23%, adult males 26%/26% (Penn et al. 2000). In Port Stephens, New South Wales, where dog attack is significant, mortality of subadult females was 39%, adult females 23%, subadult males 40%, adult males 40% (Lunney et al. 2004).

7.2 Genetic and Morphological Variation

Three subspecies of koala have been described but their validity has been questioned by genetic and morphological analyses (Takami et al. 1998; Houlden et al. 1999). The subspecies boundaries are along state boarders, but these boundaries are unlikely to represent natural barriers to koala dispersal, so populations on either side are unlikely to be isolated from one another. Southern koalas can be distinguished from northern koalas by physical features such as fur colour and size. However, the variation is considered to be predominantly clinal, changing gradually along the distribution of the koala in response to different environmental conditions (Bergmann's rule), although some regional variation is apparent (Melzer 1995).

At the national scale Houlden et al. (1999) examined variation in mitochondrial DNA from over 200 individuals from 16 populations. Their principal conclusion was that there was a lack of support for the separation of the subspecies and tentative support for a single evolutionarily significant unit for the species. Individual populations were strongly differentiated, suggesting limited gene flow and a pattern of isolation by distance. Gene flow has been further restricted by contemporary habitat fragmentation. The appropriate management unit for koalas was suggested to be the local population (Houlden et al. 1999). The exception to the trend of population differentiation was the majority of Victorian populations (except Strzelecki Ranges and South Gippsland) and South Australian populations, which are all descendants of island populations in Victoria because of their translocation program.

Latitudinal clines may reflect important differences of adaptation to factors such as temperature, and there may also be east-west differences in adaptation. Therefore, loss of all the sub-populations in any one part of the range could reduce the ecological amplitude of the species and would certainly diminish the genetic variation (Sherwin et al. 2000).

Sherwin et al. (2000) noted that no studies had enough detail to allow mapping of the boundaries between management units. Additional studies have been undertaken since then that examine genetic variability at smaller scales. In the south east Queensland region known as the Koala Coast, a 375 km^2 area in the eastern part of Brisbane, koalas have been shown by microsatellite analysis to be distinct from adjacent populations and should be considered a distinct management unit (Lee et al. 2009). This differentiation was interpreted to be recent, as a function of isolation due to barriers to dispersal imposed by roads and urban development.

Similar research has been conducted in other areas of New South Wales, but is still in the preliminary stages (Lee 2010 personal communication). In western Sydney, three populations with very limited gene flow between them have been identified (Lee et al. 2010).

7.3 Movement/dispersal

The koala is not territorial and the home ranges of individuals extensively overlap (Ellis et al. 2009). Individuals tend to use the same set of trees, but generally not at the same time. They spend a lot of time alone and devote limited time to social interactions (Martin and Handasyde 1999). Home ranges are variable depending on the location, with those in “poorer” habitats being larger than those in higher quality habitats. Males usually have larger home ranges on average than do females. For example, at Blair Athol in central Queensland, home ranges were estimated at 135 ha for males and 101 ha for females (Ellis et al. 2002), while at Bonville south of Coffs Harbour New South Wales they were estimated at 20 ha for males, and approximately 10 ha for females (Lassau et al. 2008).

Koalas tend to move little under most conditions, changing trees only a few times each day. There is little evidence for longer movements by individuals though dispersing individuals, mostly young males, may occasionally cover distances of several kilometres over land with little vegetation (Ellis et al. 2009). In south east Queensland, the average distance between natal and breeding home ranges was similar for males and females, at approximately 3.5 km (Dique et al. 2003b). Maximum dispersal distances were up to approximately 10 km for males and females (Dique et al. 2003b). Other studies have reported moves of up to 11 km in Tucki Tucki Reserve in New South Wales (Gall 1980) and 16 km in rural south east Queensland (White 1999).

7.4 Habitat and Diet

Koalas inhabit a range of temperate, sub-tropical and tropical forest, woodland and semi-arid communities dominated by eucalypt species (Martin and Handasyde 1999). The distribution of koalas is also affected by altitude (limited to <800m ASL), temperature and, at the western and northern ends of the range, leaf moisture (Munks et al. 1996).

The koala is a leaf-eating specialist. Its diet is restricted mainly to foliage of *Eucalyptus* species. It may also consume foliage of related genera, including *Corymbia, Angophora* and *Lophostemon* and at times supplement its diet with other species, including species from the genera *Leptospermum* and *Melaleuca* (Martin and Handasyde 1999; Moore and Foley 2000). While koalas have been observed sitting in or eating up to 120 species of eucalypt (Phillips 1990), the diet of individual koalas is usually limited to obtaining most of their nutrition from one or a few species present at a site (Moore and Foley 2000). Species-level preferences may also vary between regions or seasons (Moore and Foley 2000). Consequently, assessment of habitat quality for koalas has been based on the identification of local preferences for species and quantification of the local availability of those species (Phillips and Callaghan 2000; Phillips et al. 2000).

Koalas also show strong preferences between individual trees within species (Hindell et al. 1985; Martin 1985a). Captive no-choice experiments show that the chemical anti-feedants may limit or prevent koalas feeding on foliage of individual trees even when the species is considered preferred (Lawler et al. 1998; Moore et al. 2005). This variability creates a nutritional patchiness such that species-based assessments of habitat is likely to result in over-estimates of the availability of high quality habitat (Moore and Foley 2005; Moore et al. 2005; Moore et al. in press).

Leaf chemistry, and thus feeding choices, are also influenced by elevation and temperature (Moore et al. 2004), water content in semi-arid areas (Munks et al. 1996) and soil nutrients (Moore and Foley 2000 and references therein). Soil nutrients, and their influence on leaf nutrients, may be particularly important. Koalas are able to maintain positive nitrogen balance at a foliage concentration of slightly above 1% (Cork 1986). However, in significant proportions of forest the foliage of many trees may be close to, or below, this threshold. For example, in the Eden forests of southern New South Wales most arboreal marsupials are concentrated in less than 10% of the forest, and this corresponds closely with the most fertile soils (Braithwaite et al. 1983). The majority of forests do not support another eucalypt folivore, the greater glider *Petauroides volans* (Braithwaite et al. 1983) and foliage nitrogen concentrations in those forests are close to, or below, the threshold of 1% below which koalas cannot maintain a positive nitrogen balance (Cork 1986; Moore and Foley 2000).

When koala populations reach high densities they can change the species composition of the eucalypt community. This is apparent in some areas of Victoria and South Australia where koalas have been introduced and become over-abundant, causing the deaths of preferred food trees (Menkhorst 2004 and 2008). It has been suggested that koalas may impose selective pressure on favoured eucalypts, causing evolutionary divergences among related sympatric species (Moore et al. 2005).

7.5 Population Dynamics

Phases of population crashes and recovery associated with rainfall variability occur in the semi-arid west of the koala's distribution (Gordon et al. 1988; Gordon and Hrdina 2005). In these regions the riparian zones offer a refuge from drought where a subset of the population may persist. In more extreme circumstances, there may also be substantial variability in survival rates along watercourses. Gordon et al. (1988) describe koalas along dry stretches of creek occurring at lower density, being in poorer condition and suffering higher mortality during the drought, than those in habitat adjacent to permanent water. During drought the population persists in lower numbers but, following drought-breaking rain they expand out from riparian zones to occupy adjacent habitat as population size increases. While more than 63% of the individuals in the Mungalalla Creek population died in less than a year, Gordon et al. (1988) considered that survival of the population itself was not threatened.

It has also been suggested that population fluctuations associated with over-browsing may be at least partly a natural occurrence, as a function of the temporal and spatial variability in food resources and the koala's dispersal ability (Martin 1985b). Population crashes following defoliation of food trees by over-abundant koalas are often perceived to be a modern problem of unbalanced ecosystems. However, such population crashes are reported as early as 1905 at Wilsons Promontory in Victoria (Menkhorst 2008). Notwithstanding this there is debate about how landscape change can impact on koala. In the south fragmentation of habitat may increase the likelihood of localised over-population, consequential vegetation loss followed by population impact. These circumstances could also reduce the likelihood of subsequent re-colonisation (Menkhorst 2008). In contrast Gordon et. al. (2006) report that koala can cope with extensively cleared mixed farmland habitat that still contains significant remnants if other hazards are not present.

Large fluctuations in koala populations may be a feature of koala biology, but repeat events occur over a time period that is not amenable to the short time scale of many studies. Direct observational studies may report changes in koala numbers for periods of one to a few years, but establishing a baseline against which to judge them requires the use of historical and anecdotal records. In the known history of the koala they are also confounded with habitat modification and direct impacts such as harvesting. Gordon and Hrdina (2005) used the records from the possum and koala harvest period 1906-1927 in Queensland to elucidate the trends in koala population status during that period. They describe substantial fluctuations in koala populations, with multiple contributing factors. These include declines due to the harvest (but not in all regions), disease and drought but none of these was consistently a major factor in decline or recovery (Gordon and Hrdina 2005). Gordon and Hrdina (2005) suggest that the reported rapid population increases and subsequent crashes demonstrated a south to north spread, and were associated with initial clearing and flushes of high quality eucalypt regrowth foliage. Their interpretation is that populations that perhaps were relatively stable beforehand, were freed of the constraint of limited food and increased to exceed carrying capacity and subsequently collapsed due to depletion of food. This may have implications for the koala given the current vegetation management policy in Queensland.

It is thus hard to establish a baseline against which contemporary koala populations and trends may be judged. Populations at a range of scales (local, regional) may fluctuate in response to drought or to irruptions, but their dynamics may now be significantly influenced by a range of anthropogenic factors.

8. Description of Threats

8.1 Land clearing – Habitat loss, fragmentation and/or degradation

Large scale land clearing for agricultural purposes has effectively ceased, most recently with Queensland having introduced legislation to end large scale land clearing by 2006. Prior to this, land clearing was a significant cause of mortality to koalas, particularly in the Brigalow Belt Bioregion (Cogger et al. 2003). However, even without further clearing there is likely to be an ongoing "debt" to be paid, as extinction processes continue to operate on habitat patches that are now too isolated or small to support viable populations (Cogger et al. 2003; McAlpine et al. 2006a; McAlpine et al. 2007). Habitat fragmentation may also impede post-drought recovery of koala populations.

The effects of habitat loss and fragmentation may be greater than is indicated simply by estimating the proportion of land cleared. Land clearing is focussed disproportionately on flatter, more fertile areas, which constitute high quality habitat, so that what remains is often the poorer quality habitat on steep terrain and/or poorer soils (McAlpine et al. 2006a; McAlpine et al. 2006b). The impact of fragmentation and habitat isolation is also influenced by the relative hostility of the intervening habitat matrix. Urban environments, with higher densities of roads and dogs, exacerbate the effect, while in rural settings, greater isolation has relatively less impact (White 1999; Gordon et al. 2006; McAlpine et al. 2006a; McAlpine et al. 2006b). For a given amount of habitat available, a landscape of more numerous, smaller patches is less likely to be occupied than one of fewer, larger patches (McAlpine et al. 2006a; McAlpine et al. 2006b).

Urban expansion continues to threaten koalas, particularly in coastal regions. This is particularly the case as urban development brings with it the additional threats of predation by dogs and vehicle strike. The most stark example of this in the Greater Brisbane area of South East Queensland where the koala population of the Koala Coast declined by 64% over 10 years, from 6246 (4802-7691 95% confidence limits) estimated by (Dique et al. 2004) to 2279 this is considered to be approaching functional extinction (Queensland Department of Environment and Resource Management 2009a). In the Pine Rivers District, to the north of the Koala Coast, the urban population of koalas declined by 45%, and the bushland population by 15% in a similar timeframe (GHD 2008), leading to an overall decline of 40% from an estimated 4600 (Dique et al. 2003a) in 2001 to less than 2700 in 2008 (GDH 2008). Koala populations in all SEQ coastal local government areas (Sunshine Coast; Moreton Bay; Brisbane; Redland; Logan; and Ipswich) appear to be following a downward trend, as evidenced by a rapid increase in the numbers of sick, injured and dead koalas (as a consequence of development activities), followed by a decline in reporting due to a crash in koala numbers. It is also likely that the drought between 2001 and 2007 has had an impact on these populations (McDonnell 2010).

Local extinctions of small populations have occurred in the past and have highlighted the need for recognition of metapopulation structure, and the need for facilitating movement of individuals between smaller areas (Lunney et al. 2002). However, a recent study on the koala population at Port Stephens suggests that even relatively large populations (up to 800 individuals) may be vulnerable to extinction and that this vulnerability will be increased with further fragmentation (Lunney et al. 2007). It is therefore expected that koala populations in coastal New South Wales will continue to decline (Lunney et al. 2007; Lunney et al. 2009).

Koala habitat may also be lost due to logging, however the effect at the population level is a function of the management regime. For example, while clear felling will remove habitat, koalas may persist in selectively-logged forests (Kavanagh et al. 1995; Kavanagh et al. 2007). Thus the level of threat posed by logging is situation-specific and is determined by the appropriateness of the management regime, and adherence to its prescriptions. Koalas have also been recorded to have established home ranges within revegetated eucalypt woodlands.

8.2 Dogs and Cars

Dogs and cars are two threats to koalas that are closely associated with urban expansion, with exposure to both increasing as land adjacent to koala habitat is developed and occupied. However, while these threats are most intense in the urban and peri-urban environment, both may be threats in rural areas (Crowther et al. 2010). As both directly cause mortality of individuals they are treated here together.

Data on mortality of koalas is often collected by koala care groups and some of those data were provided to inform this nomination. The data provided by care groups demonstrates that mortality from dogs and cars occurs wherever koala habitat is in proximity to urban environments and it is not restricted to the South East corner of Queensland. However, there are difficulties with the use of these data for several reasons: 1. The catchment area, and distribution of search effort over that area, is often not defined; 2. It is unclear what proportion of incidents go unreported; 3. The size of the population from which the incidents are drawn is often unknown, and 4. There may be considerable overlap in the areas for which different groups report.

To illustrate the last point, data were provided by the Friends of the Koala (FoK – Lismore), Currumbin Wildlife Sanctuary (CWS), Australian Wildlife Hospital (AWH) and the Queensland Department of Environment and Resource Management (DERM). Friends of the Koala take injured animals for which they are unable to care to both CWS and AWH. Currumbin Wildlife Sanctuary occasionally transfers animals to AWH, and DERM report data for their own Moggill Koala Hospital and AWH. Consequently, the mortality data derived from DERM (Table 1) are used below as they provide the best overall estimate of mortality within a relatively defined region and they address the other three problems with this type of data.

Table 1. Mortality of koalas in South East Queensland (derived from Queensland Department of Environment and Resource Management 2009b). n.b. These data are only for

those koalas that were located and presented to the koala hospitals and thus underestimate mortality by an unknown amount.

Year	Dog	Car	Disease	Combination (cars, dogs, disease)	Other	TOTAL DEATHS
1997	103	259	273	162	29	826
1998	63	230	244	220	44	801
1999	84	261	324	214	28	911
2000	93	304	451	333	41	1222
2001	106	320	300	386	38	1150
2002	100	344	251	396	41	1132
2003	95	346	179	451	35	1106
2004	73	331	224	425	59	1112
2005	65	240	295	307	32	939
2006	65	272	167	446	66	1016
2007	66	266	159	561	76	1128
2008	38	248	198	378	72	934
2009	31	73	69	259	36	468
Total	**982**	**3494**	**3134**	**4538**	**597**	**12745**

* 2009 figures up until September only.

Between 1997 and September 2009 in south east Queensland at least 982 koalas were killed by dogs and 3494 were killed by cars (Queensland Department of Environment and Resource Management 2009b). An additional 4538 deaths were attributed to a combination of cars, dogs and/or disease. While it is not possible to ascribe each of these deaths to a particular koala population, the substantial declines noted above for the Koala Coast and Pine Rivers populations suggest that such mortality rates are unsustainable in this area. The mortality due to vehicles alone on the Koala Coast area of south east Queensland has been formally assessed (Dique et al. 2003c). At a time when the koala population was estimated at approximately 6250 (Dique et al. 2004) mortality due to vehicle strike alone averaged some 281 koalas/year. This equates to an annual mortality rate of approximately 5% due to vehicle strikes.

Another example comes from the Tilligerry Peninsula of Port Stephens. The Hunter Koala Preservation Society has collected data on rescues for this defined area within the Port Stephens Local Government Area. In 1995 38 koalas were found dead, or died after rescue (29 attributed to dogs or vehicles). The Port Stephens koala population at the time was estimated to be 350-800 animals (Lunney et al. 2007). The data from this subset of the habitat suggest mortality of 5-10%. Since 1995 the number of mortalities has declined linearly to less than half that level. As road deaths can be an indicator of abundance for animal species (Mallick et al. 1998) this may indicate a substantial decline in the population. This interpretation is supported by the modelling of Lunney et al. (2007) which indicated a likely rapid decline in the Port Stephens koala population, even under their base model (which included dog attack as a major source of mortality but did not include vehicles). It is also noteworthy that the Port Stephens Council has had a Comprehensive Koala Plan of Management (CKPoM) since 2002. Coffs Harbour City Council in 1999 was the first council to implement a CKPoM. A recent review of its effectiveness concluded that actions to protect koalas from road risk had been only partially achieved and those to protect koalas from dogs had not been achieved such that there was no indication that the plan had "reversed the trend of koala population decline" (Eco Logical Australia 2006).

Mortality due to dogs and cars has been invoked as a threat to koala populations throughout much of their range (Canfield 1991; Menkhorst 2004; Ward and Close 2004; Lassau et al. 2008; NSW DECC 2008; Natural Resource Management Ministerial Council 2010). Despite growing awareness of the problems, and attempts to address them, there is little evidence that such management responses have been effective thus far.

8.3 Disease

The most well known disease present in koala populations until recently is associated with chlamydia (Natural Resource Management Ministerial Council 2010). Many koalas carry chlamydia, but do not always show clinical symptoms (known as chlamydiosis). The symptoms include eye, urinary tract, respiratory tract and reproductive tract infections, and the latter can lead to infertility in female koalas (Natural Resource Management Ministerial Council 2010). Although the epidemiology of chlamydiosis is not well understood there is circumstantial evidence that chlamydiosis might increase in response to environmental stresses such as over-crowding and poor nutrition (Melzer et al. 2000 and references therein),.

Reduced female fertility caused by chlamydia infection may limit the reproductive potential of koala populations (NSW DECC 2008). Chlamydiosis may contribute to local declines or extinctions in small, isolated populations, where recruitment rates between populations are low and mortalities from other threats are high (NSW DECC 2008). However, through reducing female fertility, chlamydiosis may also prevent some koala populations from reaching very high densities and over-browsing their food trees (NSW DECC 2008). The South Australian and French Island (Victoria) populations are thought to be chlamydia-free, but the disease is present throughout the remainder of the species' range (Martin and Handasyde 1999). Recent research has shown that up to half of south east Queensland koalas have detectible reproductive disease likely to result in infertility (Hanger and Loader 2009).

Another recently discovered disease may have significant implications for koala conservation. Koala Retrovirus (KoRV) was recently identified and is thought to be responsible for a range of conditions, including leukaemia (Tarlinton et al. 2005) and an immunodeficiency syndrome. Up to 100% of koalas in Queensland and NSW have KoRV, but the proportions are lower in southern populations (Tarlinton et al. 2006; Hanger and Loader 2009; Lee submitted 2009) which until recently showed none of the associated conditions (Bodley in Hanger and Loader 2009)(see below). There is some evidence that chlamydiosis may be exacerbated by KoRV (Tarlinton et al. 2005).

Koala Retrovirus has endogenised in koalas (Tarlinton et al. 2006) in Queensland and New South Wales. That is, it has infected germ line cells (spermatozoa or oocytes) and is transmitted genetically (by inheritance) from parents to offspring. Although this is a known mechanism of transmission, KoRV may also spread from koala to koala (horizontal spread) by close contact, and from infected mothers to their joeys via the milk, in a manner similar to the way that many other retroviruses spread (Hanger 1999). The effects of disease on koala populations are of growing concern (Lunney et al. 2002; Hanger and Loader 2009; Queensland Government 2009); this is particularly the case in south east Queensland and northern New South Wales. The south east Queensland koala hospital data (Table 1) report 3134 deaths attributable to disease in the years 1997-September 2009, with an additional 4538 due to a combination of cars, dogs and disease (Queensland Department of Environment and Resource Management 2009b).

Recently a change in the method of recording the data has occurred. In the past where the main cause of mortality may have been recorded as disease these cases are increasingly being attributed to the "combination" category. Consequently, there is a strong negative correlation between the number of deaths attributed to disease and those attributed to "combination" (Table 1). Thus disease as a primary cause of death has apparently declined from over 30% to approximately 20% of overall mortality. However, this category alone is equivalent to the mortality due to vehicles (described above) and when the combined category is added they have been consistently around 60% of the causes of mortality of koalas in south east Queensland over 10 years. Indeed 60% of mortality in the recent Koala Coast declines was attributed to disease (Queensland Department of Environment and Resource Management 2009a). The mortality data reported by koala care groups support the observation that disease is a significant contributor to overall mortality: Hunter Koala Protection Society (mean 16%, range 6-47%), Friends of the Koala (41% 2009), Coffs Harbour City Council (30% 1999-2002, 15% 2003-2006), Currumbin Wildlife Hospital (46% 2000-2009), Native Animal Trust Fund (20% 2009).

While the above focuses on the growing recognition of disease as a threat to koalas in a particular region, it is also recognized elsewhere. Both the Victorian and New South Wales state governments acknowledge that disease should be considered a threat to koala populations in some circumstances, particularly where they combine with other threats (Menkhorst 2004; NSW DECC 2008). Increasing incidence of KoRV has recently been reported on Kangaroo Island, along with the first reported case on the island of lymphoma (Koala Research Network 2010).

It has been suggested that the effects of disease may be exacerbated by the effects of habitat fragmentation and associated stress (Melzer et al. 2000; NSW DECC 2008). Hanger and Loader (2009) offer an alternative view, suggesting that the disease threat is significant and independent of habitat fragmentation. However, they note that this does not detract from the need to protect habitat, but rather that it requires better information on the effects of disease on population dynamics in addition to those induced by habitat fragmentation directly.

8.4 Climate change and drought

Drought is a natural phenomenon that has occurred, and will continue to occur, irrespective of the extent to which predicted climate change scenarios prove accurate. However, as a hypothesised effect of climate change is more frequent and/or more intense drought, the two are considered together here.

Climate change is a potential threat to the koala, as it is expected to lead to increased temperatures, changes to rainfall, increasing frequency and intensity of droughts and increased fire risk over much of the koala's range (Natural Resource Management Ministerial Council 2010). Increased temperatures inland are expected to cause the koala's range to contract eastward (Dunlop and Brown 2008; Queensland Office of Climate Change 2008; Adams-Hosking 2009; Steffen et al. 2009). This effect would be compounded by extended drought that may be expected under climate change scenarios (Queensland Office of Climate Change 2008). In the south of the koala's range, in Victoria, more hot days, increased risk of intense fire and more droughts are expected (Victorian Department of Sustainability and Environment 2009). Adams-Hosking (2009) estimated, using bioclimatic modelling, that the koala's range, and particularly its core (10-90%) range, would contract by 20-30% by 2030.

In the west and north of their range in Queensland, the distribution of koalas is determined by heat in combination with water availability (Munks et al. 1996; Sullivan et al. 2003b). This is reflected in a tendency to find the highest densities of koalas along creek lines. Anecdotal evidence suggests that the distribution of koalas in south west Queensland contracted eastwards in response to drought in the 1920s (Sullivan et al. 2003b). Sullivan et al. (2003b) also noted that koalas were concentrated in the north and central portions of their study area and decreased to the south and west consistent with rainfall patterns. In Mungalalla Creek a koala population crashed by at least 63% in the summer of 1979-80 in response to a continued drought (Gordon et al. 1988). Gordon et al. (1988) suggested that the regional persistence of koalas may rely on the protection of 'survival' habitats around permanent water holes, from which koalas may disperse into other habitats as conditions allow (but see below). The length of the drought may also have significant implications for the capacity of a population to recover. Gordon et al. (1988) noted that dominant adults were more likely to occupy refuge habitat, such that younger individuals died earlier in the drought.

In research undertaken in 2003-2009 in northern and central western Queensland, near Hughenden and at Moorinya National Park, koalas were at very low densities and confined to drainage lines where extensive searching was required to locate them (reported at the National Koala Abundance Workshop, convened by the TSSC in November 2009). There is evidence of tree dieback along drainage lines and this is exacerbated by the practice of landowners building small dams on creek lines, with subsequent death of downstream vegetation. In central Queensland (such as at Springsure and Tambo) koala densities have also declined markedly, although density appears to be stable at Norwood Creek where the presence of the more drought tolerant *Eucalyptus crebra* (Melzer 1995) provides a food source not available to koalas elsewhere. Here also, mature eucalypt trees were stressed or dying back along drainage lines and koala populations were contracting to refuge areas where water is more reliable.

Thus, under climate change projections there is expected to be a general eastwards shift in the edge of the distribution (Adams-Hosking 2009). Discussion at the National Koala Abundance Workshop noted that this is complicated by hydrological changes that do not necessarily follow this directional trend. It is expected that, if recovery occurs, it will include a phase shift in riparian communities, with *E. camaldulensis* replacing *E. tereticornis*. *Eucalyptus camaldulensis* is more drought tolerant, but grows at lower densities so that, if there is a post-drought recovery, koala populations may be expected to re-establish but stabilise at a lower density. This was the case at Mungalalla Creek following a drought-induced population crash in the 1980s (Gordon et al. 1988). However, the expert workshop noted that tree age in western Queensland and New South Wales is much greater than previously appreciated, such that the ability of these habitats to recover from drought is much lower than has been estimated previously even if moister conditions return. The deaths of trees substantially older than normal drought cycles may be indicative of a process not part of normal climate cycles and indicative of a long term or permanent decline (Carrick 2010 personal communication). Recent Queensland legislative protection of high value regrowth has extended protection to more than one million hectares of koala habitat.

The Mulga Lands bioregion in south western Queensland was estimated in the 1990s to have some 59 500 koalas, occupying riparian habitats but also extending out at lower densities into expansive surrounding habitats (Sullivan et al. 2003a; Sullivan et al. 2003b; Sullivan et al. 2004). A severe population decline is indicated as a result of the recent drought (Baxter 2009 personal communication; Seabrook et al. 2010). The drought has led to the distribution of koalas contracting to riparian areas and, overall, towards the north east. The density of koalas on Sullivan's 'residual' habitats is now extremely low. Using the same methods as Sullivan et al., a preliminary estimate at the height of the recent drought of 29 050 (range 22 970-37 500) koalas was calculated for the region (Seabrook et al. 2010). This is a substantial decline from Sullivan et al.'s 44 000-78 000 (mean 59 555).

While there are no new data for the semi-arid north western region of NSW, the trends are likely to be consistent with those observed for the adjacent western Queensland part of the koala's range. Days of extreme heat have been identified as a threat to koalas in the Pilliga forests (Kavanagh and Barrott 2001; Kavanagh et al. 2007). Given that climate change scenarios for the western part of the koala's range suggest higher temperatures and less rainfall overall, and more extreme hot days each year, there is potential for the distribution of the koala to be reduced permanently in New South Wales and in Queensland.

Drought may also be a factor in the decline in koalas in coastal south east Queensland (McDonnell 2010), where the substantial decline has largely been attributed to habitat fragmentation, disease, vehicle strike and predation by dogs (see above). McDonnell (2010) notes that many of the secure habitats where koalas had declined in the 2008 survey

(Queensland Department of Environment and Resource Management 2009a) are on drier sites. He also suggests that drought-related stress may have made koalas more susceptible to disease. McDonnell (2010) also suggests that if drought was a significant factor in that decline, there should be observable signs of recovery via higher fecundity rates after the end of the drought, which has occurred in 2010. These data are not yet available.

In the southern part of the koala's range, in Victoria, the effects of climate change may be manifest in, or exacerbated by, their influence on the fire regime. In recent times devastating fires have occurred (e.g. Victoria's Black Saturday in 2009 and wildfires in Pilliga 1998 and 2006) and in 2009 governments introduced a new fire risk category (Catastrophic). The mortality of koalas resulting from these fires has not been quantified, but loss of habitat was extensive and koalas are particularly exposed to injury in crown fires that occur in these intense bushfires. The National Koala Abundance Workshop noted that a substantial proportion of koala habitat has been burned in Victoria in recent years. A recent study of the influence of fire and other factors on koalas in Port Stephens suggested fire is a significant threat to koalas, but that changing the fire regime may not improve the population's viability. That is, changing the regime from infrequent, large fires to more common, smaller fires did not improve modelled population viability (Lunney et al. 2007).

Increasing atmospheric CO_2 will have effects independent of climate change *per se*. When eucalypts are grown under elevated CO_2 the ratios of carbon to nitrogen in the foliage increase such that concentrations of carbon-based anti-herbivore compounds like tannins increase while nitrogen (protein) decreases (Lawler et al. 1997). It has recently been shown that the balance between tannins and proteins determines protein digestibility and that subtle differences may have profound effects for reproductive success of eucalypt folivores (Degabriel et al. 2009). Tannins reduce the availability of nitrogen for digestion, such that a measure of "available" nitrogen is necessary to elucidate the role of leaf nitrogen in herbivore demography. Degabriel et al. (2009) showed that female common brushtail possums *Trichosurus vulpecula* with home ranges containing trees with greater nitrogen availability have higher fecundity and produce offspring that grow faster and have greater overall fitness. Thus the results "*suggest a link between the combined effects of plant nutrient concentration and chemical defence, and reproductive fitness, which is important for explaining patterns of distribution and abundance in plant-mammal systems*" (Degabriel et al. 2009). Not all nitrogen in eucalypt foliage is available to koalas (Cork et al. 1983), indicating the negative effect of tannins on protein digestibility. Koala population dynamics could be negatively impacted by the changes in leaf chemistry induced by elevated CO_2. It is not yet possible to assess forest nutritional quality over much of the koala's range, and thus to quantify the effect described above.

8.5 Habitat degradation due to over-browsing

Much of the substantial population of koalas in Victoria and South Australia live in areas where over-population is a significant problem. The density of koalas is so high that they may damage the food trees on which they depend, resulting in a substantial population crash, such as has occurred a number of times in Victoria (e.g. at Framlingham, Walkerville, Sandy Point) (Martin 1997; Martin and Handasyde 1999; Menkhorst 2008).

A range of options has been used to address the over-population problem, principally translocation and sterilisation. It was reported at the National Koala Abundance Workshop that with substantial management effort the koala population of Kangaroo Island has been reduced by approximately 40% following sterilisation of some 10 000 koalas, of which 3000 were translocated to the mainland (Duka and Masters 2005). The National Koala Abundance Workshop also noted that koala populations have also been reduced in some Victorian populations, again with substantial effort: at Mt Eccles National Park, some 8000 koalas have been sterilised over several years and the population has been reduced to approximately 6000 from approximately 11 000 in 2004. It is often noted that this expenditure comes at the cost of conservation efforts for other species (Duka and Masters 2005) and it will have to continue into the future indefinitely. While culling has been suggested to be one of the few logistically feasible ways to reduce populations before they reach the point where habitat damage occurs, it is considered an unacceptable alternative (Martin 1997; Tabart 1997; Menkhorst 2008; Natural Resource Management Ministerial Council 2010).

Significant large populations may not be amenable to control by sterilisation. Large populations occur at Otway and Strathbogies Ranges and are not subject to fertility control (Menkhorst 2008) so remain vulnerable to resource depletion and rapid and substantial population decline (Martin 1997). Current management aims to maintain koala population density at or below one koala per hectare to prevent over-browsing and damage to habitat is (Menkhorst 2004; Duka and Masters 2005). It was reported to the National Koala Abundance Workshop that in 2009 koala densities in some manna gum (*E. viminalis*) stands of Cape Otway were up to 17.1 koalas per hectare. Substantial loss of manna gums in the area, and a crash in the koala population, is a likely outcome.

8.6 Reduced genetic variability

A function of the translocation program in Victoria is that large populations of koalas began with only a very few individuals (Menkhorst 2008). Most populations in both Victoria and South Australia were established, or re-established, via individuals from islands in Victoria’s Westernport Bay. Those source populations were themselves founded from a small number of individuals. As a consequence, genetic variability is low across most Victorian and South Australian koala populations and they have suffered severe bottleneck and founder effects (Houlden et al. 1996; Seymour et al. 2001; Cristescu et al. 2009).

The studies of Seymour et al. (2001) and Cristescu et al. (2009) both investigated the relationship between genetic diversity and testicular abnormalities. Seymour et al. (2001) compared inbreeding across several populations and identified a correlation between the level of inbreeding and the proportion of the population exhibiting testicular abnormality. Cristescu et al. (2009) did not find the same trend when they examined the relationship between an estimate of an individual animal’s level of inbreeding and testicular abnormality, within the Kangaroo Island population. However, they cautioned that this should not be seen as definitive as the high proportions of abnormalities means the genes are widespread and can be passed on without the individual’s parents necessarily being closely related. In addition to the abnormalities considered above, inbreeding also has effects on testicular and sperm morphology, and thus on reproductive characteristics of male koalas (Montogomery 2002).

The above studies caution that the high numbers of individuals should not be taken to indicate that the populations are genetically safe. The majority of Victorian koalas, and all South Australian koalas, are derived from a limited number of individuals and thus represent little genetic capital (Houlden et al. 1996; Seymour et al. 2001; Cristescu et al. 2009). The impact of observed testicular abnormalities in some South Australian populations (Seymour et al. 2001; Cristescu et al. 2009) on individual or population fertility rates is unknown. However, the inbreeding coefficients measured for all southern Australian koala populations examined to date are above a threshold where extinction is considered substantially more likely (Frankham 1995; Houlden et al. 1996; Seymour et al. 2001; Cristescu et al. 2009). Low genetic variability, as exhibited by both Victorian and South Australian populations, also reduces the population’s ability to adapt to change, which may exacerbate the effects of disease, over-browsing or climate change (Houlden et al. 1996; Seymour et al. 2001; Cristescu et al. 2009). The Koala Research Network has raised concern about the vulnerability of these populations to KoRV (Koala Research Network 2010).

9. Public Consultation

The nomination was made available for public exhibition and comment for 30 business days. The Committee has had regard to all 223 responses to consultation that was relevant to this listing advice.

10. How judged by the Committee in relation to the criteria of the EPBC Act and Regulations

Criterion 1: It has undergone, is suspected to have undergone or is likely to undergo in the immediate future a very severe, severe or substantial reduction in numbers

There is at present no published scientifically peer-reviewed estimate of the total number of koalas in Australia and no definitive past estimate within an appropriate timeframe to enable comparison. The report on the 1986-7 national survey of koala distribution noted that a total population size was "impossible to estimate as survey techniques varied greatly from area to area" (Phillips 1990). Similarly, in the previous assessment of the koala's national status, the TSSC noted that there have been no direct measurements of change in the size of the national koala population over the past three generations (Threatened Species Scientific Committee 2006).

Nevertheless, it is necessary here to consider the available information on numbers of koalas in different areas to enable consideration of the comparative influence of identified trends in numbers or distributions in those areas when considered against the national scale. For example, while one population may be shown to be growing and another declining, the overall effect can only be judged with some evaluation of their relative size. The available information on population numbers and trends is presented below at the scale of regions within states, before synthesising them to evaluate the likely national trend.

South Australia

The main South Australian population is the introduced one on Kangaroo Island. In 2001 the population was estimated to be 22 000 to 27 000 koalas (Masters et al. 2004). Since 1997 there has been an extensive program of translocation (3000 koalas) and sterilisation (10 000 koalas) aimed at reducing over-browsing pressure on the habitat. The National Koala Abundance Workshop heard that approximately 30-60% of the population was sterilised, and the population had reduced to between 12 000 and 16 000 by 2006.

On the mainland there are four other populations at Eyre Peninsula, the Riverlands, Lucindale (a single population within 10 ha) and the Adelaide Hills. Those in the Lucindale area show some abnormalities of the skull consistent with inbreeding. There are no formal estimates of population size available, but over-population may possibly be an issue in the Adelaide Hills (Natural Resource Management Ministerial Council 2010).

Victoria

The size of the koala population in Victoria is very much a function of the translocation program that has been operating for several decades. Most potential koala habitat now has established koala populations. According to evidence presented at the National Koala Abundance Workshop, Victoria has koala populations in a range of circumstances, grouped into four broad categories: High population densities (Mt Eccles NP, Otways etc.), Medium density/large area (Ulupna Island, Brisbane Ranges etc.), Low density stable (You Yangs NP, Wilsons Promontory etc) and Low density declining (Macedon Ranges, Phillip Island). The population total summed to roughly 73 500, however these are estimates and there have been few detailed surveys in some areas. This estimate is considerably lower than previous estimates for Victoria, such as the estimate of >100 000 animals on the Strathbogie Ranges alone (Martin 1997). This is most likely to be a function of a difference in the method of calculating the estimate. However, Martin has noted that his recent observations in the Strathbogie Ranges suggest that the population has declined, based on reduced sightings of koalas overall, reduced proportion of females with back young, fewer road-killed koalas and tree death due to drought (Martin 2010 personal communication).

Northeast NSW

North-eastern NSW is often held to be the stronghold of koalas in the state. While population densities tend to be highest in this part of New South Wales, there are few contemporary estimates of the size of koala populations and it is not possible to give an overall estimate. However, there are data to assess the distribution of koalas which give a coarse indication of population density (Lunney et al. 2009). Lunney et al. (2009) reported results of a community survey to estimate changes in distribution and relative abundance between 1986 and 2006, and noted that most of the areas in NSW that indicated decline were in the north east. Of the populations for which population information is available, Iluka is considered to have gone extinct (Lunney et al. 2002) and Port Stephens had a population of 350-800 koalas in 1998 (Lunney et al. 2007). However, Lunney et al. (2007) modelled the available population parameters for Port Stephens and showed that it was susceptible to decline unless mortality due to fire and dogs were both eliminated. Lake Innes Nature Reserve was reported to have a population of approximately 600 koalas in 1999 (NSWNPWS 1999) while adjoining freehold lands comprising the remainder of the Innes Peninsula and associated Thrumster planning area collectively support an associated population of approximately 300 koalas (Forsman and Phillips 2005; Phillips 2008). In the Lismore area there is evidence that koalas may be extending their range into eucalypt forest/woodland that has become established since clearing of the Big Scrub rainforest (Lee submitted 2009).

Thus the number of koalas in north east NSW is uncertain, and population audits are required to establish current population size.

Central coast NSW and Sydney Bioregion

In the Sydney Basin Bioregion koalas occur around the Central Coast, Blue Mountains and the fringes of the Cumberland Plain. Records from reserves are uncommon, though they are found in Dharug, Wollemi and Tomaree NPs. There are scattered records through the South Eastern Highlands Bioregion. The Campbelltown (and surrounding areas) population of south west Sydney has been increasing slowly since the 1980s and is considered to have approximately 300 animals. Given the large areas of National Park in the Sydney region, low density koala populations may support several hundred individuals (Close 2010 personal communication). A number of other small populations are identified in the NSW recovery plan but these are likely to be small and some (e.g. Pittwater) may now have gone extinct (NSW DECC 2008).

Northwest NSW

In New South Wales west of the Great Dividing Range key populations occur at Pilliga and Gunnedah, with smaller populations elsewhere (NSW DECC 2008). The Pilliga population is important as it has been estimated to support some 15 000 koalas (Kavanagh and Barrott 2001). However, this estimate has been questioned because of mapping and recording matters (NSW DECC 2008), and may be a significant over-estimate. The estimate is also now 10 years old and the Pilliga has been subject to severe drought in the interim. In areas where koalas were once abundant in the 1990s they were rare or absent at the height of the drought (Parnaby 2010 personal communication).

Despite formal studies of the koala population (Smith 1992; Curran 1997), there are no quantitative estimates of population size for Gunnedah. State-wide surveys of koala distribution indicate that the Gunnedah population is regionally significant (Crowther et al. 2009) and has expanded, against the state trend, due to revegetation aimed at addressing soil salinity problems (Lunney et al. 2009). However, the proximity of plantings adjacent to roads and railway tracks creates high exposure of koalas to vehicle strike, and a heatwave in 2009 led to high mortality (Crowther et al. 2010).

Southern NSW

A synthesis of recent koala surveys was prepared for the purposes of this nomination by Chris Allen of NSW DECCW, combining the results of surveys conducted using a variety of means (Allen 2009). Densities for all areas were uniformly low or very low. The combined estimates for the region from approximately Goulburn south to the New South Wales border sums to approximately 800 koalas. Allen (2009) notes some indications of an increase in the population in the coastal forests north east of Bega, but it must be noted that this is an extremely small population. Recent intensive surveys show that a population at Tantawangalo/Yurammie is now very low and possibly extinct.

North Queensland

There are no published estimates of koala population size or density in the far northern part of the koala's range in the Wet Tropics and Einasleigh Uplands bioregions. There are some anecdotal reports of koala sightings but these are uncommon and suggestive of very low densities. The northern limit of the distribution of the koala in Queensland has contracted to the south from approximately Cooktown to inland of Cairns since the late 1960s (Phillips 1990; Gordon et al. 2006).

Northwest Queensland

There are again no published estimates of the number of koalas in this region, but some formal survey work has been undertaken to assess density. In the Desert Upland bioregion koalas occur in very low density, such that surveys of the animals were considered impractical and faecal pellet surveys were used instead to assess relative abundance (Munks et al. 1996). Munks et al. (1996) found that koalas were principally associated with creek lines and leaf moisture was probably a critical determinant of their occurrence.

It was reported at the National Koala Abundance Workshop that at sites to the west of the study area of Munks et al. (1996), in the Mitchell Grass Downs bioregion, koalas have been surveyed at Moorinya National Park in August 2000 and February 2003. With six people conducting intensive searches over two days along creek lines (areas most likely to support koalas) they found only traces of koalas in 2000 and one dead koala in 2003. At Hughenden, to the northwest of Moorinya, searches by five people over five days, covering over 16 km of drainage lines over four consecutive years (2006-2009), found an average of 2.25 koalas per year.

There are no prior estimates of koala density against which to compare the above figures. However, it is notable that distributional surveys in 1967 and 1977 recorded koalas well to the west of these sites, while they are close to the western edge of distribution recorded in the more extensive 1986/1987 national survey (Phillips 1990). This may indicate an eastward contraction of the koala's distribution (Gordon et al. 2006).

Central Queensland

Koalas have been studied at Tambo (Mitchel Grass Downs bioregion), Springsure and Blair Athol (both in Brigalow Belt North bioregion). Koalas in this region typically occur at low densities and have large home ranges (Ellis et al. 2002). The most recent estimates were provided to the National Koala Abundance Workshop for Tambo and Springsure. At Tambo densities were very low, with only two and three koalas (one of which was dead) found in 2008 and 2009 respectively, in extensive searches of approximately 10 km of creek lines.

Data are available for four sites at Springsure in 1992 and 2009 (Table 2). The koala density was estimated via intensive searches of 1 km^2 plots, and declined from an average of 0.155 to 0.01 koalas/ha (a decline of >90%). There was no decline at the Norwood Creek site, initially the lowest density of the sites, where *Eucalyptus crebra*, a more drought tolerant species, is dominant. At the other sites the dominant tree species, *E. tereticornis* has undergone extensive mortality.

Table 2. Density of koalas (/ha) at fixed 1km^2 sites surveyed in 1992 and 2009

Site	1992	2009
Wallalee	0.4	0.02
Koala Creek	0.15	0.0
Pinnacle	0.05	0.0
Norwood Creek	0.02	0.02

Southwest Queensland

Significant research work has been undertaken in the Mulga Lands bioregion, with a method for estimating koala abundance from faecal pellets developed and calibrated for the local conditions (Sullivan et al. 2002). In 1995 the koala population of the Mulga Lands was estimated at 59 500 (44 500 - 75 600 95% confidence limits) (Sullivan et al. 2004). Sullivan et al. (2004) also estimated a decline in koala numbers of approximately 10% due to land clearing in the preceding 30 years. During this survey a substantial proportion of koalas were in habitat on residual landforms away from riparian areas.

However, the climate in western Queensland is highly variable, with drought a characteristic feature of the region. More recently, the koala population in the region has been estimated, using the same methods as Sullivan et al. (2004), to be 29 050 (range 22 970-37 500), representing a decline of approximately 50% (Seabrook et al. 2010). Seabrook et al. (2010) also noted that they expect the decline in numbers to be a significant over-estimate for a sub-set of the region where they could not sample due to adverse weather. The koala distribution has contracted under drought conditions to the riparian areas, with very few koalas currently using the habitat on residual landforms as observed by Sullivan et al. (2004). Heavy rains occurred through much of the region in early 2010 and drought declarations for the region have been removed as at 31 July 2010 (Queensland Department of Environment and Resource Management 2010).

Southeast Queensland

Attempts to derive population estimates for the southeast Queensland region have been focussed particularly on the Koala Coast and Pine Rivers Shire (the latter now part of Moreton Bay Regional Council). The Koala Coast had an estimated 6246 (4802-7691 95% confidence limits) koalas in 1996-1999 (Dique et al. 2003a). That population had declined by some 65% to 2279 koalas in 2008 and was expected to fall further (Queensland Department of Environment and Resource Management 2009a). Pine Rivers Shire supported approximately 4600 koalas in 2001 (Dique et al. 2003a) and this declined by 40% to less than 2700 koalas in 2008.

In the Gold Coast region the koala population was estimated at 4,724 koalas (4316 - 5131 (95% confidence limits)) in 2007 (Phillips et al. 2007). This estimate includes a population of 510 koalas (381 - 639) inhabiting the Coomera-Pimpama Koala Habitat Area where already approved development will see over a third of the resident koala population lost. Anticipated further development will see additional losses, while an escalation of associated threats (e.g. cars, dogs) will invariably lead to further population decline. The population is likely to be rendered unviable (in the absence of an assertive management response) once incidental mortality arising from the associated threats referred to above, exceeded 6% of total population size (Phillips 2007).

Koala populations in all SEQ coastal local government areas (Sunshine Coast; Moreton Bay; Brisbane; Redland; Logan; and Ipswich) appear to be following a similar downward trend to the Koala Coast and Pine Rivers populations, as evidenced by a rapid increase in the numbers of sick, injured and dead koalas, followed by a decline in koala numbers . Further north, koala populations are less well known, often becoming known as a result of development applications, but are generally considered to be at low density (<0.2 koalas/ha) (White et al. 2005; Queensland EPA 2006).

Australian Capital Territory

The koala population of the ACT is likely to be very small. There have been at least six introductions from Victoria but no large or dense populations have ever become established. There have been no reports of wild koalas following a bushfire in 2003 (Fletcher 2009 personal communication).

Overall synthesis of koala trends

The Committee acknowledges that there are substantial uncertainties in the estimates of koala population sizes and trends across the species' national range. While some regions or populations are very well studied, for many others there are few data or a lack of a baseline against which to formally evaluate population trends. Nevertheless, there is sufficient information to enable inferences to be made about some regional population trends, despite the inherent uncertainty in the data.

Estimates provide evidence of decline of Kangaroo Island's translocated population due to management intervention for habitat protection.

The major consideration in koala management in Victoria is the protection of habitat, and koala populations, from damage due to over-browsing. The Victorian government has devoted substantial resources to this issue and is achieving reasonable success across several populations. The koala population of Victoria can be considered to be broadly stable at the state level, although individual population trajectories may vary. The current koala population estimate of Victoria is significantly reduced from the numbers used in previous assessments, but this is probably mostly due to a refinement of the method of population estimation and thus cannot be taken as evidence for a decline. Nevertheless, while stability of the population at the state level is assumed here, the Committee notes that high density populations of koalas at Otway Ranges and the Strathbogie Ranges are not currently subject to active management and remain vulnerable to over-browsing. Notwithstanding the above there are similar pressures on some Victorian koala populations associated with mortality caused by cars, dogs and urban development to those faced by koala populations in New South Wales and Queensland.

In New South Wales, no reliable overall state estimate is available. The New South Wales Koala Recovery Plan estimates the total number of koalas in New South Wales is between one to ten thousand but notes that there is considerable uncertainty about the total number of koalas in New South Wales (DECC, 2008). For populations in northern and central coastal New South Wales, the available evidence suggests ongoing declines in areas subject to developmental pressures. The evidence is via a combination of models suggesting decline is likely in recent years, incidental data on declines (e.g. care group reports) and reported failure of management measures. The exception to the coastal trend is the central coast region where small koala populations, such as Campbelltown, may be increasing slowly while others may be extinct (e.g. Pittwater).

The published estimate for the koala population of the Pilliga Forests, in the northwest of the koala's NSW distribution, is large and thus exerts a strong influence on the state trend. The 1998 estimate was approximately 15 000 koalas, and the Pilliga has since been subject to wildfire and severe drought, such that an extreme population decline has been reported.

These spot data do not include any estimates of the koala population in the extensive areas of National Parks and State Forest that lay astride the Great Dividing Range and adjoining lowlands from Goulburn to the Queensland border.

For koala population and trend estimate, Queensland is also problematic because of the koala's wide distribution to the north and west, and the lack of quantitative data in those regions. The sheer extent of the koala's distribution within the state, over several large bioregions, corresponds to a very large initial population at any reasonable measure of density. There are quantitative estimates at appropriate times for the Mulga Lands and South Eastern Queensland bioregions, but the remainder of the Queensland population must be estimated from land area multiplied by very localised estimates of koala population density. The Committee judges that a reasonable estimate baseline (i.e. 3 generations ago) figure for Queensland is approximately 300 000 koalas with a plausible range of 180 000 to 550 000. Because of the high relative size of the Queensland population, the trend in this state has a strong influence on the national trend.

There are limited direct data by which to evaluate the decline in the inland Queensland koala population. However, the following may be collated to provide an indication of the scale of decline. Population estimates over the Mulga Lands bioregion suggest a decline of 50% due principally to drought. The population at Springsure (Brigalow Belt North bioregion) has declined by up to 95% over a similar timeframe, and the Blair Athol population (Brigalow Belt North) is reported to have declined by an unspecified amount and breeding to have ceased. Additional recent reports are of very low densities of koalas at Hughenden, Tambo (Mitchell Grass Downs bioregion) and Moorinya National Park (Desert Uplands bioregion), along with reports of extensive dieback of riparian koala food trees. Again this could be due to drought.

Tree dieback has also been reported over areas of the Brigalow Belt and this bioregion has been extensively cleared and the koala habitat fragmented. Additionally, there are some indications that the koala's distribution has contracted from the north and the west in Queensland. Cumulatively, these data present a strong inferential case for a substantial decline in koala numbers and question about the capacity for population recovery in the short to medium term. The Committee considers that these data are sufficient to infer a significant decline in the Queensland population.

Combining the estimated changes in koala populations has high degrees uncertainty associated with it. The Committee considers that the national population may have declined by about 30% over three koala generations. Despite this the Committee has considerable uncertainty that the figure it has reached and recommends that a final conclusion would require that critical data gaps are filled.

The Committee recommends that this could be achieved by giving urgent attention to koala population distribution and demographics in Queensland and New South Wales.

Criterion 2: Its geographic distribution is precarious for the survival of the species and is very restricted, restricted or limited

The koala is endemic to Australia. It has a widespread distribution in coastal and inland areas of eastern Australia, from north-east Queensland to Eyre Peninsula in South Australia. The koala's range extends over approximately 22^{o} of latitude and 18^{o} of longitude, and encompasses at least one million square kilometres (Martin and Handasyde 1999). The koala's distribution is not continuous across this range and it occurs in a number of populations that are separated by cleared land or unsuitable habitat (Martin and Handasyde 1999; NSW DECC 2008).

The Committee does not consider that the species' geographic distribution is both precarious for the survival of the species and very restricted, restricted or limited. Therefore, as the species has not been demonstrated to have met the required elements of Criterion 2, it is **not eligible** for listing in any category under this criterion.

Criterion 3: The estimated total number of mature individuals is limited to a particular degree; and either

(a) evidence suggests that the number will continue to decline at a particular rate; or

(b) the number is likely to continue to decline and its geographic distribution is precarious for its survival

As described under Criterion 1, the koala population is greater than 200 000 individuals, with large populations in a number of locations over four states.

The Committee does not consider that the estimated total number of mature individuals of the species is very low, low or limited. Therefore, as the species has not been demonstrated to have met the required elements of Criterion 3, it is **not eligible** for listing in any category under this criterion.

Criterion 4: The estimated total number of mature individuals is extremely low, very low or low

As described under Criterion 1, the koala population is greater than 200 000 individuals, with large populations in a number of locations over four states.

The Committee does not consider that the estimated total number of mature individuals of the species is extremely low, very low or low. Therefore, as the species has not been demonstrated to have met any required element of Criterion 4, it is **not eligible** for listing in any category under this criterion.

Criterion 5: Probability of extinction in the wild that is at least

(a) 50% in the immediate future; or

(b) 20% in the near future; or

(c) 10% in the medium-term future

While there have been Population Viability Analyses conducted for individual populations (Penn et al. 2000; Lunney et al. 2002) there are insufficient data available to estimate a probability of extinction of the whole species in the wild over a relevant timeframe. Therefore, as the species has not been demonstrated to have met the required elements of Criterion 5, it is **not eligible** for listing in any category under this criterion.

11. Conclusion

Conservation Status

The koala has an extensive distribution that spans four states and the Australian Capital Territory. Collectively this represents an area of occupancy of over one million square kilometres. The status of individual populations varies across this range, but human impact pressures overall have increased over time and act to exacerbate the effects of, or impede the recovery from, natural pressures such as drought. Where koala habitat coincides with growing human populations and urban development, koala habitat continues to be cleared despite a range of preventative management measures, and koalas in remaining habitat areas continue to be vulnerable to threats from dogs, cars and disease. The extent to which these inland populations may recover from the most recent drought remains uncertain. The vulnerability of koala populations to these effects is increased by the loss of habitat due to clearing and the fragmentation this has produced in the landscape.

The koala population has undergone a marked decline over three koala generations, due to the combination of a range of factors. The Committee considers the koala to be potentially eligible for listing as vulnerable. However, as noted under Criterion 1, better demographic data are required to make this judgement with confidence.

12. Recommendations

The Committee recommends that the list referred to in section 178 of the EPBC Act not be amended at this time by including the *Phascolarctos cinereus* **(**koala) in the list in the Vulnerable category.

Associate Professor Robert J.S. Beeton *AM FEIANZ*

Chair

Threatened Species Scientific Committee

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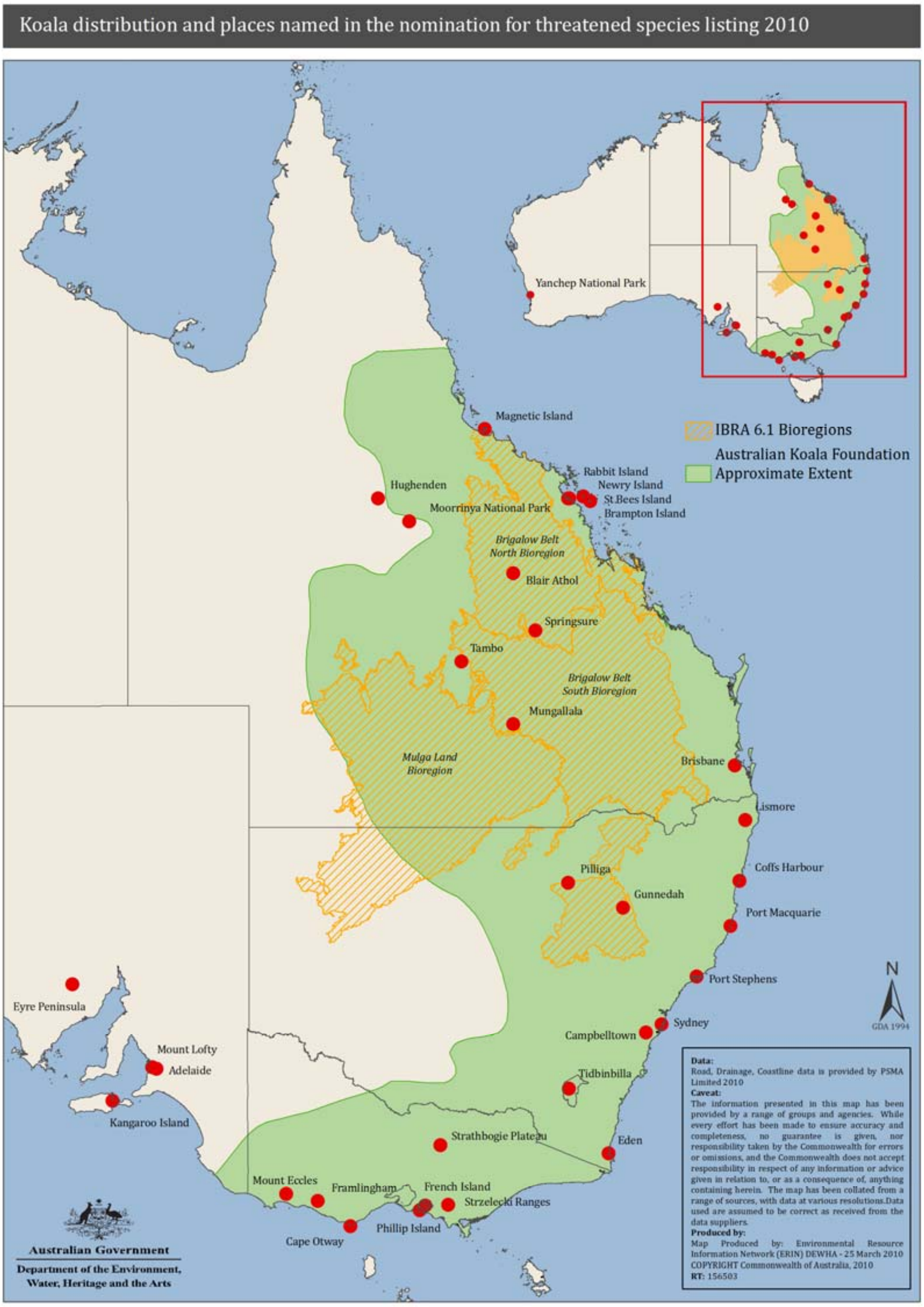

Figure 1. Distribution of the koala and places named in the text of the nomination for listing as a threatened species under the *Environment Protection and Biodiversity Conservation Act (1999).*