Advice to the Minister for Sustainability, Environment, Water, Population and Communities 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)

Summary

This advice considers the conservation status of the koala *Phascolarctos cinereus* at two levels – across its entire range, and for the Queensland-New South Wales-Australian Capital Territory portion of its range. This advice revises that previously given by this Committee in September 2010, through the consideration of new information mostly arising from the Senate Inquiry (Senate Environment and Communications References Committee 2011).

Of the five eligibility criteria relevant for conservation listing, the koala approaches or meets only that criterion relating to the extent of population decline over a three generational period (in the koala's case, 20 years). The data available for this assessment remain extremely patchy, inconsistent and incomplete. The Committee considers that, at the national level, the koala's decline over the last 20 years approaches but does not meet the required eligibility threshold (loss of 30% of total population size). Accordingly, the Committee advises that the koala is ineligible for listing as threatened at the national level.

However, the Committee recognises that the koala faces stark conservation challenges across much of its distribution, particularly in the northern portion of its range. If the koala populations in Queensland and New South Wales (along with the very small koala population within the Australian Capital Territory) together are considered as a designatable "species" for the purposes of the EPBC Act, then their rate of decline over the last 20 years readily meets the eligibility threshold for listing as vulnerable. Such a listing would deliver a conservation benefit most focused at the koala's major management concerns.

The Committee notes that the circumscription of a "part-range" population and its treatment as a species under the Act has few precedents, and that these few cases involved populations that were notably more distinct and disjunct than that of the "northern" population of koala. The Committee advises that it recognises a pressing priority to develop sound guidelines for the application of "part-range" designations.

1. Name

Phascolarctos cinereus.

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

2. Reason for Conservation Assessment by the Threatened Species Scientific Committee

The Threatened Species Scientific Committee (the Committee) provided advice to the Minister on 30 September 2010, finding the koala ineligible for listing as vulnerable. Although there had been a marked decline over the species' national range, there was too much uncertainty in the population data to be confident that the decline warranted threatened species status. While the Minister was considering this recommendation, a motion calling for a Senate inquiry into the status, health and sustainability of Australia's koala population was passed, on 17 November 2010.

The Minister decided to defer his decision until the Senate inquiry reported, in the expectation that additional information gathered by the inquiry could resolve the uncertainty around the koala's status. The Senate inquiry's report "The koala – saving our national icon" was released on 22 September 2011 (Senate Environment and Communications References Committee 2011). The report noted that the most prominent issue raised during the inquiry was whether the koala should be listed as a threatened species. The Senate committee declined to offer their own view on the matter due to a lack of technical expertise, but made recommendations that the Minister and the TSSC reconsider the matter on the basis of information provided in submissions to, and appearances before, the Senate committee.

The Minister subsequently requested the Committee's advice on the following recommendations from the Senate report:

- **Recommendation 5:** ...that the Threatened Species Scientific Committee review its advice to the Minister on the listing of the koala in light of the findings of this inquiry.
- **Recommendation 17:** The (Senate) committee recommends that the Environment Minister consider options to improve the conservation status of the diverse and rapidly declining koala populations in New South Wales and Queensland to ensure a nationally resilient population is maintained. These options include listing the koala as vulnerable under the EPBC Act in areas where populations have declined significantly or are at risk of doing so.

2.1. Circumscription of part-range populations

With respect to the latter recommendation (#17 above) the Committee has here adopted the approach of "designatable units" (Green 2005). The designatable unit approach acknowledges that while the fundamental conservation unit is the species, in some circumstances there is value in identifying units below the species level and assessing their status separately such that conservation efforts are more appropriately focussed to achieve the best conservation outcome. Designatable units may be subspecies or other taxonomically distinct groupings, but such units can be difficult to resolve (e.g. see Taxonomy section below). Thus a further pragmatic extension of designatable units is to make a division at the highest geographic level where variation in conservation status within each unit can be adequately described by a single category. Divisions at smaller scales are inappropriate as they provide no greater resolution and thus offer no advantages in prioritising conservation efforts.

The Committee here determines that the most appropriate designation is to treat the combined populations of Queensland, New South Wales and the Australian Capital Territory as a single designatable unit. The Committee recommends that the Minister determine the combined populations of Queensland, New South Wales and the Australian Capital Territory to be a "species for the purposes of the Act" under s517 of the EPBC Act. The Committee did not formally consider other permutations of koala populations (for example, the Queensland population alone, or that of south-eastern Queensland), on the grounds that its responsibility lies chiefly with the national extent, and that there is clear consistency in the threats affecting koala populations (and the management actions required to address these threats) across the koala populations in Queensland, New South Wales and the Australian Capital Territory.

The detailed supporting data for this recommendation are to be found below, but are summarised briefly here. The division between the two designatable units is the state border between New South Wales and Victoria. The status of the koala differs significantly because of the history of translocation in Victoria and South Australia that has led to large populations in several areas in these states, including some that require active management to suppress population growth to prevent habitat damage. The Victorian koala population is large and the evidence suggests broadly stable at present. In contrast, in Queensland, New South Wales and the Australian Capital Territory there has been no systematic program of translocation, habitat loss has been extensive, koalas are exposed to a suite of ongoing threats and populations show declining trends in most areas. The designatable unit consisting of the combined koala populations in Queensland, New South Wales and the Australian Capital Territory is supportable on the basis of a substantial variance in conservation status and resulting focus of conservation management within and external to it

There is some morphological and genetic variation across the koala's extensive range, but the Committee notes that the case is weak for circumscribing the combined koala populations in Queensland, New South Wales and the Australian Capital Territory as a biological "entity" on such grounds.

3. Summary of Conclusion

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

The Committee judges that the designatable unit, consisting of the combined koala populations in Queensland, New South Wales and the Australian Capital Territory, has been demonstrated to have met sufficient elements of Criterion 1 to make it **eligible** for listing as **Vulnerable.**

4. Taxonomy

The species is conventionally accepted as *Phascolarctos cinereus* (koala) (Goldfuss, 1817). Three subspecies of koala have been described: *Phascolarctos cinereus adustus* (Queensland) (Thomas 1923), *P. c. cinereus* (New South Wales) (Goldfuss 1817 in (Iredale and Troughton 1934) and *P.c. victor* (Victoria) (Troughton 1935). These were dismissed (treated as synonyms) in the most recent taxonomic revision (McKay 1988), but are currently recognised by the Australian Biological Resources Study (see discussion below under 7.2 Genetic and morphological variation).

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 widely distributed in coastal and inland areas from north-eastern Queensland to Eyre Peninsula in South Australia (see Figure 1 attached at end – map showing distribution and places named in the text). The range extends over 22^{o} of latitude and 18^{o} of longitude, or about 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).

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 may be introduced but recent anecdotal evidence suggests that they may be natural (Lee 2010; 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 occur 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).

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).

The greatest density of koalas in the State occurs in south-east Queensland, and lower densities occur through central and eastern 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).

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, small populations are known from 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 populations occur in the Strathbogie Ranges, Cape Otway, South Gippsland (including the Strezlecki 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).

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 (Melzer et al. 2000).

Koalas were introduced to Kangaroo Island from French Island (Victoria) in the 1920s. Kangaroo Island now supports a large population of koalas, which put unsustainable browsing pressure on preferred food tree species such as manna gum (*Eucalyptus viminalis*). Consequently this population 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) and possibly New South Wales, and 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 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. The koala has been the subject of a variety of conservation plans, including a national strategy developed in 1998 and revised in 2009. Additionally, the koala is the subject of a state management strategy in Victoria (2004), a recovery plan (2008) and specific state environmental planning policy in New South Wales and a conservation plan in Queensland (2005). The Queensland plan has been repeatedly modified as part of the Queensland koala response strategy.

Status

- Queensland - *vulnerable* throughout the South East 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.
- 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 2011 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 [1]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 (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 annual mortality 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, northern 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 lines, but there are few barriers to dispersal of koalas across these boundaries and the subspecies are unlikely to be truly isolated. Southern koalas can be distinguished from northern koalas by physical features such as fur colour and body 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).

The most informative study at the national scale is that of Houlden et al. (1999) who examined variation in mitochondrial DNA from over 200 individuals from 16 populations. Their principal conclusion was a lack of support for the separation of the species into subspecies and tentative support for a single Evolutionarily Significant Unit[2] (Moritz 1994) 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. As a result of this analysis, 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 (Lee et al. 2011)) and South Australian populations, which are all descendants of island populations in Victoria as a result of translocation programs.

These 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 at the time of their paper, 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 koalas of the Koala Coast, a 375 km^2 area in the eastern part of Brisbane,

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[1] Generation length is the average age of parents of the current cohort (i.e., newborn individuals in the population)

[2] The term evolutionarily significant unit (ESU) is used to designate populations that have diverged significantly over evolutionary time. An ESU identifies a geographically discrete set of historically isolated populations.

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. The Koala Coast cluster contained few alleles that were not also present in adjacent mainland populations; however, the remainder of the mainland koalas had many alleles that were not present in the Koala Coast animals (Lee 2010). In the same PhD study distinct population clusters were identified in adjacent New South Wales, around Lismore (Lee 2010) which are likely indicative of colonisation of the area by koalas from the north.

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 ranges in "poorer" habitats larger than in higher quality habitats. On average, males usually have larger home ranges on average than do females. For example, at Blair Athol in central Queensland, home ranges are estimated at males 135 ha, females 101 ha (Ellis et al. 2002) while at Bonville in New South Wales they were estimated at males 20 ha, female approximately 10 ha (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 in most cases (Ellis et al. 2009), though dispersing individuals, mostly young males, may occasionally cover distances of several kilometres over land with little vegetation. 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 species from the genus *Eucalyptus* (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 is usually based on the identification of local preferences for species and quantification of the 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 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 likely result in overestimates 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). 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). The majority of these forests do not support another eucalypt folivore with similar nutritional requirements to the koala, the greater glider *Petauroides volans* (Braithwaite et al. 1983) suggesting that these forests do not have enough available nitrogen to support large folivores (see also Section 8.4).

Where koala populations reach high densities they may affect the composition of the eucalypt community, through preferential herbivory. This is apparent in some areas of Victoria and South Australia where koalas have been introduced and become overabundant, causing the deaths of preferred food trees (Menkhorst 2004, 2008). 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 episodes of drought-breaking rainfall, may 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.

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 occurred as early as 1905 at Wilsons Promontory in Victoria (Menkhorst 2008). Menkhorst (2008) notes that fragmentation of habitat may increase the likelihood of overpopulation and consequential vegetation and then population impact, and reduce the likelihood of subsequent recolonisation.

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. Thus their interpretation is that relatively stable populations were freed of the constraint of limited food and increased to exceed overshot carrying capacity and subsequently collapsed due to depletion of food.

Therefore there is a high degree of uncertainty in establishing 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 are likely human influenced.

8. Description of Threats

Note:

For clarity, the range of threats to which koalas are exposed have been treated separately. However, many of the threats may act on a given koala population at the same time, and thus may be greater than is indicated by their impact considered in isolation. For example, in urban environments the effect of habitat fragmentation is exacerbated by exposure to predation by dogs and vehicle strike. While drought *per se* is a natural phenomenon and thus may not be considered a threat under some circumstances, the potential for increased drought frequency or severity is considered under climate change.

8.1 Habit 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. 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 “extinction debt” (Tilman et al. 1994) 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 for koalas, 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. Urban development also brings the additional threats of predation by dogs and vehicle strike (see below). 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 an estimated 6250 (4802-7691 95% confidence limits)(Dique et al. 2004) to 2280 koalas, and is considered to be approaching functional extinction (Queensland Department of Environment and Resource Management 2009). 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. 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) (see below under Climate Change).

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 clearfelling 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

Additional potential threats to koala habitat include Bell Miner Associated Dieback (BMAD) and myrtle rust. BMAD occurs patchily from South-East Queensland to Victoria but the area of greatest concern is north-eastern New South Wales and it is recognised as a Key Threatening Process (KTP) by the NSW government (http://www.environment.nsw.gov.au/determinations/bellminerfd.htm). BMAD affects wet and dry sclerophyll forest communities often dominated by eucalypts. The KTP determination cites the koala as occurring in forests damaged by BMAD in New South Wales. Myrtle rust is a recently arrived fungal pest of plants of the family Myrtaceae, including eucalypts (http://www.dpi.nsw.gov.au/biosecurity/plant/myrtle-rust). It is now found extensively across eastern New South Wales and Queensland and has infected over 90 plant species. A small number of koala food tree species have been infected but these infections have been minor to date such that myrtle rust does not appear to be a current threat to koala habitat.

8.2 Encounter mortality - 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 also be threats in rural areas (Crowther et al. 2010; Senate Environment and Communications References Committee 2011). As both directly cause mortality of individuals they are treated here together.

Data on mortality of koalas are 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 close to urban environments. Such mortality is not restricted to the South East corner of Queensland (detailed below). 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, Currumbin Wildlife Sanctuary, Australian Wildlife Hospital and the Queensland Department of Environment and Resource Management. Friends of the Koala take injured animals for which they are unable to care to both Currumbin Wildlife Sanctuary and Australian Wildlife Hospital. Currumbin Wildlife Sanctuary occasionally transfers animals to Australian Wildlife Hospital, and Queensland Department of Environment and Resource Management report data for their own Moggill Koala Hospital and Australian Wildlife Hospital. Consequently, the mortality data derived from Queensland Department of Environment and Resource Management (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.

Between 1997 and May 2011 in south east Queensland at least 1144 koalas were killed by dogs and 4055 were killed by cars (Queensland Department of Environment and Resource Management 2011). An additional 5757 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. 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 strike alone (note that this is not necessarily the rate of population decline as it does not include other causes of mortality nor births or migration).

Table 1. Mortality of koalas in South East Queensland (derived from Queensland Department of Environment and Resource Management 2011). 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	105	278	268	163	42	856
1998	69	237	250	225	62	843
1999	87	266	332	234	59	978
2000	95	311	450	361	82	1299
2001	114	324	303	398	90	1229
2002	103	342	245	381	73	1144
2003	94	342	180	475	83	1174
2004	68	333	238	436	93	1168
2005	60	234	262	314	96	966
2006	69	280	193	425	88	1055
2007	68	287	179	588	90	1212
2008	58	296	256	435	97	1142
2009	76	248	210	630	108	1272
2010	67	246	131	567	88	1099
2011*	11	31	19	125	21	207
Total	**1144**	**4055**	**3516**	**5757**	**1172**	**15644**

* 2011 figures up until May only.

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 alone suggest mortality of 5-10%. Since 1995 the number of mortalities has declined linearly to less than half that level. As trends in 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. In a submission to the Senate inquiry, the CKPoM Steering Committee noted "Unfortunately, despite the CKPoM being in place, the simple fact is that loss of Koala habitat through vegetation clearing, fragmentation of existing habitat, cars, disease and dogs are the significant causes of the dramatic population decline in Port Stephens." Coffs Harbour City Council was the first council to implement a CKPoM in 1999. 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). There is circumstantial evidence that chlamydiosis might increase in response to environmental stresses such as overcrowding and poor nutrition (Melzer et al. 2000 and references therein), although the epidemiology of chlamydiosis is not well understood.

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). Hanger and Loader (2009) also caution that the ultrasound method used to detect the disease likely underestimates its prevalence.

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 2010) 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). Whether KoRV can be transmitted by biting insects has yet to be determined.

The effects of disease on koala populations are of growing concern (Lunney et al. 2002; Hanger and Loader 2009; Queensland Government 2009), particularly 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 2011). Due to a change in the method of recording the data, where the main cause of mortality may in the past 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 2009). 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 discussion focuses on the growing recognition of disease as a threat to koalas in a particular region, the threat of disease 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 (Senate Environment and Communications References Committee 2011), 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 the major influences of climate change are anticipated to manifest via more frequent and/or more intense droughts, climate change and drought 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; Steffen et al. 2009; Adams-Hosking 2011; Adams-Hosking et al. 2011). 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 (consistent with the three generation timescale of the listing criteria), leaving bioregions such the Mulga Lands, Mitchell Grass Downs and Einasleigh Uplands uninhabitable by koalas (Adams-Hosking 2011).

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 at higher densities in the north and central portions of their study area than in the south and west, consistent with rainfall patterns. In Mungalalla Creek, in the Mulga Lands bioregion, 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. It may be hypothesised that this is an appropriate adaptation for shorter droughts, but if the drought is extended beyond a generation, there may be little recruitment. As a result the population of reproductive individuals is very low when the drought ends.

In research reported at the National Koala Abundance Workshop (convened by the TSSC in November 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. There is evidence of tree dieback along drainage lines and this situation 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.

Under climate change projections there is expected to be a general eastwards shift in the edge of the distribution of koalas (Adams-Hosking et al. 2011). Discussion at the 2009 National Koala Abundance Workshop noted that this situation 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, as illustrated by the Mungalalla Creek population 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).

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 2002/2003 drought (Seabrook et al. 2011). A general decline in rainfall has led to the distribution of koalas contracting to riparian areas and, overall, towards the north east of the bioregion. The density of koalas on Sullivan’s ‘residual’ habitats is now extremely low. Additional declines may continue to occur as the koala population adjusts to habitat loss and fragmentation since the cessation of clearing (akin to ‘extinction debt’ *sensu* Tilman et al. (1994)). Using the same methods as Sullivan et al (2004), a more recent estimate of 11 600 (9 843-13 430 95%

confidence limits) koalas was calculated for the region (Seabrook et al. 2010). This is a substantial decline from Sullivan et al.'s 59 555 (44 000-78 000 95% confidence limits). As noted above, Adams-Hosking (2011) suggests the bioregion may not be able to support koalas by 2030.

While there are no recent data for koala populations in 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 invoked as a threat to koalas in the Pilliga forests (Kavanagh and Barrott 2001; Kavanagh et al. 2007) and anecdotal information suggests a substantial population decline occurred with the recent drought (Parnaby 2010 personal communication). 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 significantly reduced permanently in New South Wales and in Queensland.

Drought may also be a significant factor in the decline in koalas in coastal south east Queensland (McDonnell 2010), where the substantial decline has largely been attributed to habitat fragmentation, 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 2009) 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. These data are not yet available. Nevertheless, other sources of mortality as described above remain severe, particularly with the population size much diminished.

In parts of the koala's range, the effects of climate change may be manifest, or exacerbated, by their influence on the fire regime. In recent times devastating fires have occurred (e.g. Victoria's Black Saturday, 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. A substantial proportion of koala habitat has been burned in Victoria in recent years (Senate Environment and Communications References Committee 2011). 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 are likely to 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 overbrowsing

Many koalas in Victoria and South Australia live in areas where overpopulation 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 several 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 overpopulation problem, principally translocation and sterilisation. These interventions have been effective in managing some smaller populations but the logistics and costs may be prohibitive for larger populations. Menkhorst (2008) estimates that the currently favoured option of sterilisation via hormone implants costs approximately $200 per animal. Additionally, the extensive program of relocation in Victoria has been so successful in re-establishing populations that there are few available options for translocation and future management will need to rely more heavily on *in situ* sterilisation. Modelling suggests that a target for sterilisation to produce significant population declines is in the order of 70% (McLean 2003; Duka and Masters 2005). With substantial management effort (Duka and Masters 2005), it was reported at the 2009 National Koala Abundance Workshop that 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. 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 Cape Otway and in the Strathbogie 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). The National Koala Abundance Workshop heard 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 Low 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).

Seymour et al. (2001) and Cristescu et al. (2009) investigated the relationship between genetics 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 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 visible abnormalities considered above, inbreeding also has effects on testicular morphology 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 secure. 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 (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 (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 the survival of the species. The Committee has also considered information provided to the Senate inquiry into the status, health and sustainability of Australia's koala population.

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

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

The Committee judges that the designatable unit, consisting of the combined koala populations in Queensland, New South Wales and the Australian Capital Territory, has been demonstrated to have met sufficient elements of Criterion 1 to make it **eligible** for listing as **Vulnerable.**

The data provided below are first considered at a regional (or equivalent) level within states, before syntheses of the data against Criterion 1 both for the national population and the combined koala populations in Queensland, New South Wales and the Australian Capital Territory.

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[3] 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).

Estimates of koala population size at regional and national levels remain highly divergent and contested. For many regions, there have been no surveys or published population estimates. Nonetheless, for this criterion to be evaluated, the Committee has attempted to compile or estimate population size for the requisite baseline year (around 1990) and currently (2011), across all portions of the koala's range. This is a challenging task, and our assessments will be open to criticism. In tabular summaries in the sections below, we provide the rationale for our assessments, and indicate the level of confidence that we have in these values.

Wet Tropics and Central Mackay Coast Bioregions

The TSSC could find no published estimates of koala population size or density in the Wet Tropics and Central Mackay Coast 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).

Mitchell Grass Downs, Desert Uplands and Einasleigh Uplands Bioregions

There are no published estimates of the number of koalas in this region, but some localised formal survey work has been undertaken to assess density. In part of the Desert Upland bioregion koalas occur at 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. There are few data on the koala population of the Einasleigh Uplands.

It was reported at the 2009 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. At Tambo, well to the south but also within the Mitchell Grass Downs, 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.

[3] The indicative thresholds used by the Committee, based on IUCN guidelines, are that a very severe decline is ≥80% reduction in population size, a severe decline is ≥50% and a substantial decline is ≥30% over 10 years or three generations, whichever is the longer. In the case of the koala, the timespan is approximately 20 years.

There are no prior estimates of koala density against which to compare the above figures. However, it is notable that distributional surveys in 1967 (Kikkawa and Walter 1968) and 1977 (Campbell et al. 1979) recorded koalas well to the west of the sites described above, while they are close to the western edge of distribution recorded in the more extensive 1986/1987 national survey (Phillips 1990). This result may indicate an eastward contraction of the koala's distribution (Gordon et al. 2006).

Brigalow Belt North and Brigalow Belt South Bioregions

Koalas have been studied at Springsure and Blair Athol in this region, typically occurring in low densities and with large home ranges (Ellis et al. 2002). The most recent estimates for Springsure were provided to the 2009 National Koala Abundance Workshop.

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 (but see (Fensham and Holman 1999) who describe 29% dieback of adult trees in northern Queensland, with the *E. crebra-E. xanthoclada* complex being most susceptible). 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 at Springsure, Central Queensland, 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

Mulga Lands Bioregion

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 30 years from 1969. During this survey a substantial proportion of koalas were in habitat on residual landforms away from riparian areas.

At re-sampling using the same procedures in 2009, the koala population in the region was estimated to be 11 600 (range 9 800-13 400 95% confidence limits), a decline of approximately 80% (Seabrook et al. 2011). This represents the most substantial and robust regional-scale koala population monitoring information available, and its timing is particularly relevant to consideration of criteria for the assessment of the koala's conservation status. However, it is difficult to contextualise the observed decline relative to the national koala population change, as the mulga lands koala population is a peripheral one, at the arid limit of the koala's distribution.

In the Mulga Lands, 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). Seabrook et al. (2011) also noted that additional clearing of habitat may have contributed to the decline in koala numbers between 1995 and 2009. 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 Bioregion

Attempts to derive population estimates for southeast Queensland 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. That population had declined by 65% to an estimated 2279 koalas in 2008 and was expected to fall further (Queensland Department of Environment and Resource Management 2009). The final report of a 2010 survey of the Koala Coast Population has not yet been released, however ongoing koala mortality (Table 1) is high relative to the koala population size and thus suggests further decline has occurred since 2008. Pine Rivers Shire supported approximately 4600 koalas in 2001 (Dique et al. 2003a) and this declined by 40% to fewer than 2700 koalas in 2008.

In the Gold Coast 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).

Queensland (overall)

The Queensland Nature Conservation (Koala) Conservation Plan 2006 and Management Program 2006-2016 cites an overall figure for Queensland's koala population of 100 000 to 300 000 but gives little indication of its derivation. Specific population figures are given only for the Mulga Lands, Koala Coast and Pine Rivers (as described above) where the estimates sum to slightly more than 70 000 and declines average more than 75% since the 1990s. The remainder of the estimated figure includes the koalas in the low density populations (0.005-0.2 koalas/ha) over the remainder of their extensive distribution. The Committee has given consideration to this figure, and data available on koala densities and bioregional areas, and concludes that a plausible range of population sizes for Queensland in the 1990s is 250 000 – 350 000 koalas, with a best estimate (*sensu* (IUCN Standards and Petitions Subcommittee 2011) of 295 000. A summary of the figures used by the Committee in its consideration of Queensland's koala population are below at Table 3.

Consideration of the population trend in Queensland requires that the known population data (Mulga Lands, South East Queensland) are considered in combination with inferred population sizes and trends for the remainder of the koala's Queensland range. The majority of the koalas in these bioregions are expected to be in the Brigalow Belt, given its extensive size and more favourable conditions than Mulga Lands (the only bioregion for which data on the broadscale response to the drought are available). The Committee's best estimate consists of, on a bioregional basis, approximately: South East Queensland 25 000; Mulga Lands 60 000, Mitchell Grass Downs, Desert Uplands and Einasleigh Uplands combined 85 000, Brigalow Belt North and South 115 000 and Wet Tropics, Central Mackay Coast combined 10 000 (Table 3).

The inferred trend in the Brigalow Belt is considered to be a decline of 30-40%, somewhat less than that in the Mulga Lands, and a similar decline has been applied also to the Mitchell Grass Downs, Einasleigh Uplands and Desert Uplands bioregions in the Committee's modelling. In the absence of appropriate data, the koala populations of the Wet Tropics and Central Mackay Coast have been considered to be broadly stable. The plausible range of estimates for the inferred decline in the Queensland koala population is thus approximately 39-46%.

Table 3. Summary of the Committee's assessment of Queensland koala populations, for the time period relevant to Criterion 1.

Region	Date	Best Estimate	Range	Basis, and Assumptions	Confidence in population estimate
Wet Tropics, Central Mackay Coast	1990	10 000	n/a	Limited data, small coastal bioregions	Low
	2010	10 000	n/a	As above, less affected by the drought than inland bioregions	
Desert Uplands, Mitchell Grass Downs, Einasleigh Uplands	1990	85 000	67 000 – 107 000	Approximate area by density: Mitchell Grass Downs 0.001 koalas/ha, Desert Uplands and Einasleigh Uplands 0.005 koalas/ha.	Low
	2010	55 000	51 000 - 59 500	Decline 30-40%, range based on decline from 1990 best estimate.	Low
Brigalow Belt	1990	115 000	90 000 – 145 000	Approximate area by density: 0.005 koalas/ha	Low
	2010	75 000	69 000 - 80 500	Decline 30-40%, range based on decline from 1990 best estimate.	Low
Mulga Lands	1990	60 000	44 500 - 75 600	Taken from published paper	High
	2010	11 600	9 800-13 400	As above	High
Southeast Queensland	1990	25 000	n/a	Based on aggregate of formal estimates	High
	2010	15 000	n/a	As above	High
QUEENSLAND TOTAL	1990	295 000	250 000 – 350 000		
	2010	167 000	157 000 – 177 000		

North-east NSW

North-east NSW is often held to be the stronghold of koalas in this 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) report 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 become 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 supported 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 2010). There are substantial areas of National Park and State Forest in the region for which there are few data on population size.

Thus the number of koalas in north-east NSW is uncertain and population audits are required to establish current population size. Nevertheless, they likely numbered in the high thousands in recent times but the nature and extent of exposure to threats suggests that declines have occurred, and will continue, in many areas.

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 populations are identified in the NSW recovery plan but these are likely to be small and some (e.g. Pittwater) may now be 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, the estimate has been questioned because of mapping and recording matters (NSW DECC 2008) and may be a significant overestimate. The estimate is also now 10 years old and the Pilliga has been subject to severe drought. In areas where koalas were once abundant in the 1990s they are now rare or absent and there has been little sign of recovery (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 various methodologies (Allen 2009). Densities for all areas were low. The combined estimates for the region from approximately Goulburn south to the New South Wales-Victoria border sum 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 small and possibly extinct.

New South Wales (overall)

The Committee's New South Wales koala population estimate was based on a series of population estimates for populations at local and regional scales (summarised in Table 4). These estimates included several populations along the northern and southern coasts. The Pilliga population estimate (approx. 15 000) comprises a particularly high proportion of the overall state estimate. The Committee infers that declines have occurred for most north coast populations based on published modelling studies, a common suite of threats and anecdotal information from care groups. Anecdotal reports suggest a severe, but unquantified, decline in the Pilliga population. Based on submissions to the Senate inquiry, the estimated base New South Wales population used here is slightly larger than used in the 2009 nomination (Table 2, TSSC 2009). In its deliberations the Committee has considered the NSW population to be approximately 31 400 in 1990 and 21 000 in 2010 (approx. 33% decline). The Committee notes that the 2008 New South Wales Recovery Plan for the Koala states "The continuation of the major population centres for koalas is encouraging, but the detailed local studies which have examined population dynamics in relation to existing threats, such as land clearing, habitat fragmentation, fire, dogs and cars, identify that most of these populations are failing and that the status of the koala as being vulnerable is well justified."

Table 4. Summary of the Committee's assessment of New South Wales koala populations, for the time period relevant to Criterion 1.

Region	Date	Best Estimate	Basis, and Assumptions	Confidence in population estimate
North East	1990	10 500	Higher density than in most other parts of the state, extensive areas of National Park and State Forest.	Moderate
	2010	7 500	Declines measured or inferred via modelling studies for several urban areas, particularly along the coastal region. Data lacking for significant forested areas.	Moderate
Central coast NSW and Sydney bioregion	1990	1 500	Estimates for Campbelltown area, extrapolated based on expert advice of large area with low density populations	Moderate
	2010	1 900	Inferred increase based on expert advice on Campbelltown population.	
Northwest (other than Pilliga)	1990	2 000	Inferred based on community survey data suggesting widespread occurrence across region but with substantial areas of cleared land.	Low
	2010	3 000	Increase inferred based on unquantified increase in koala population in Gunnedah region due to revegetation	Low
Pilliga Forest	1990	15 000	Published estimate	High
	2010	7 500	Decline inferred based on drought, wildfire, anecdotal reports of substantial decline	Low
South East	1990	2 400	Published estimate for Eden-Bermagui extrapolated to broader region	Moderate
	2010	1 100	Published estimate for region.	High
NEW SOUTH WALES TOTAL	1990	31 400		
	2010	21 000		

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).

Victoria

The size of the koala population in Victoria is largely a function of the translocation program that has been operating for several decades. Most potential koala habitat now has established koala populations. In its 2010 listing advice the TSSC used an estimate of the total population for Victoria of 73 500 but the Victorian government, in its submission to the Senate inquiry, stated that this was “certainly an under-estimate”(Senate Environment and Communications References Committee 2011). However, no formal estimate was provided and thus the Committee has had to consider a broad range of estimates as plausible and to consider the influence of those values on the determination of the national trend. Additionally, there are few data by which to discern a trend in the state population but the Committee has noted the exposure of some populations to predation by dogs, vehicle strike and wildfire; and some localised increase due to revegetation. In its deliberations the Committee has considered a range of population sizes between 150 000 and 300 000 and inferred a 20 year decline in the Victorian koala population of between 5 and 10%.

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. In 2010, the population of Kangaroo Island was estimated at 13 660 (Senate Environment and Communications References Committee 2011).On the mainland there are four other populations - at Eyre Peninsula, the Riverlands, Lucindale (a single population within 10 ha) and the Adelaide Hills. There are no formal estimates of population size available, but overpopulation may possibly be an issue in the Adelaide Hills (Natural Resource Management Ministerial Council 2010). The Committee considers plausible estimates for the South Australian koala population to be approximately 32 000 in 1990 declining under direct management to 19 500 in 2010 (approx. 39%).

Overall synthesis of koala trends

National Scale

The Committee notes that there are substantial uncertainties in the estimates of koala population sizes 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 a decline. Nevertheless, there is sufficient information to gauge relative population sizes and complementary information on habitat condition or other indicators to enable inference about regional population trends, despite the inherent uncertainty in the data.

Before consolidating information on national status, we note briefly an interpretational issue relating to consideration of population management in South Australia and Victoria. The

Committee includes in its assessment of national trends all introduced populations in the range states, following the IUCN guidance that “benign” introductions should be considered in evaluating a species’ status (IUCN Standards and Petitions Subcommittee 2011). That is, although some populations occur outside the koala’s natural range, they are still included in the assessment.

The most substantial koala population in South Australia is Kangaroo Island, for which formal quantitative estimates provide evidence of a strong declining trend. This decline is the direct result of management intervention for habitat protection. Similar considerations apply to some intensively-managed Victorian populations. The managed decline in the South Australian population has relatively little influence at the national level because it is a small proportion of the national population.

The koala population of Victoria can be considered to be broadly stable or declining slightly at the state level, although individual population trajectories may vary. The current koala population estimate of Victoria is unknown but considered to be large, and thus has a buffering effect on declines in other states.

In New South Wales koala populations have declined across most of the state due to a suite of threats. The declines have been severe in many areas and the threats are ongoing. Increases in the number of koalas in Gunnedah and Campbelltown are insufficient to counterbalance the state’s declining trend.

Queensland is the state for which estimation of the overall population is most problematic for derivation of national trends, because the Queensland population probably comprises a relatively high proportion of the total Australian population (most likely 40-50%), and because estimation is difficult due to the koala’s expansive distribution to the north and west, and the lack of quantitative data in those regions. As the Committee judges the 1990 Queensland koala population to have been large, and that a substantial declined has occurred, it has a strong influence on the national trend.

Combining the estimated changes in koala populations for each of its range states, the large size and relative stability of the Victorian population tend to dampen the effect of the Queensland decline. It is pertinent here to reiterate two key changes in the available data that were identified during the course of the Senate inquiry (Senate Environment and Communications References Committee 2011). The first is that the estimated decline in the Mulga Lands bioregion in Queensland was recalculated by the researchers and increased from the 50% used in the Committee’s 2010 listing advice (Threatened Species Scientific Committee 2010) to 80% (Seabrook et al. 2011). The second is that the Committee’s 2010 listing advice relied on an estimate of the Victorian population that has been described as “certainly an under-estimate” (Senate Environment and Communications References Committee 2011) and a considerably larger population has been inferred here. The dampening effect of the Victorian estimate has thus increased, and exceeds the additional decline estimated for the Mulga Lands, such that the Committee has again determined that, at the national scale, the koala is **ineligible** for listing as **vulnerable**.

Table 5. Summary of the Committee's assessment of national koala populations, for the time period relevant to Criterion 1. Note that in South Australia and Victoria population-control programs have been operating, and that the population of the ACT is considered to be very low (fewer than a hundred) and is not included in this tally.

Region	Date	Best Estimate	Decline
Queensland	1990	295 000	
	2010	167 000	43%
New South Wales	1990	31 400	
	2010	21 000	33%
Victoria	1990	215,000	
	2010	200,000	~7%
South Australia	1990	32 000	
	2010	19 500	39%
NATIONAL TOTAL	1990	573 400	
	2010	407 500	29%
COMBINED QUEENSLAND AND NEW SOUTH WALES TOTAL	1990		42%
	2010		

Designatable Unit consisting of the combined koala populations in Queensland, New South Wales and the Australian Capital Territory

In assessing the status of the designatable unit consisting of the combined koala populations in Queensland, New South Wales and the Australian Capital Territory the Committee has had regard to the guidelines developed by the IUCN for the application of listing criteria to regional populations (IUCN 2003). These provide guidance on whether the regional population's interaction with populations of the species outside the region are sufficient to influence the category to which the species/entity is assigned within the region. In this context, the important question is whether there is potential for sufficient koalas to immigrate into the range of the combined koala populations in Queensland, New South Wales and the Australian Capital Territory to provide a "rescue" effect from the decline experienced within the region. It is the Committee's view that there is very limited potential for any rescue effect. While koalas may potentially move across the border from Victoria into New South Wales, the fact that the southern New South Wales koala populations have shown little to no recovery for an extended period indicates that any rescue effect is minimal. Additionally, this potential dispersal is only possible at the southern extreme of the ≥2000 km latitudinal range of the combined koala populations in Queensland, New South Wales and the Australian Capital Territory, rendering maintenance of adaptive potential entirely reliant on processes within the unit's boundaries. The combined koala populations in Queensland, New South Wales and the Australian Capital Territory Unit is effectively demographically independent and thus the listing criteria are applied as per a normal species-level assessment as advised by IUCN (2003).

As described above, the Committee considers the plausible range of estimates for the decline in the Queensland koala population to be approximately 39-46% while the corresponding figure for New South Wales is approximately 33% (Table 5). The baseline population size for Queensland is an order of magnitude larger than that of New South Wales and thus the trend for the combined unit is approximately the same as for Queensland alone. (If extant) the very small population of the Australian Capital Territory has no effect on the combined designatable unit. The Committee has determined that the combined koala populations in Queensland, New South Wales and the Australian Capital Territory has experienced a substantial decline, exceeding the threshold of ≥30% over three generations, and thus considers this designatable unit **eligible** for listing as **vulnerable.**

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 an area of around 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 at either the national scale or that the combined koala populations in Queensland, New South Wales and the Australian Capital Territory.

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

The koala population is described under Criterion 1. The Committee does not consider that the estimated total number of mature individuals of the species is very low, low or limited at either the national scale or that of the combined koala populations in Queensland, New South Wales and the Australian Capital Territory. 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

The koala population is described under Criterion 1. 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, or the combined koala populations in Queensland, New South Wales and the Australian Capital Territory, 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. The status of individual populations varies across this range, but pressures overall have increased over time and human impacts also 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. In northern and western parts of the koala's distribution, in Queensland and New South Wales, drought and heatwaves have had a severe impact on koala populations and the trees on which they depend for food. 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.

Conversely, koalas remain at least locally abundant in Victoria and South Australia. Some populations in these states are "over-abundant" and must be managed to reduce population density in order to prevent habitat degradation. However, other populations in these States face similar threats to koalas elsewhere, and may face further problems in the future associated with their relatively low genetic diversity.

The overall effect at the national scale is that the decline over three generations in Queensland and New South Wales is counterbalanced by the size and relative stability of the Victorian population and the species overall cannot be considered eligible for listing in any category. However, separate consideration of the combined koala populations in Queensland, New South Wales and the Australian Capital Territory removes the counterbalance effect and allows the substantial and ongoing declines within the unit to be the focus. The combined koala populations in Queensland, New South Wales and the Australian Capital Territory has undergone a substantial decline over three generations, due to the combination of a range of factors. The Committee therefore consider the combined koala populations in Queensland, New South Wales and the Australian Capital Territory to be **eligible** for listing as **vulnerable**.

Recovery Plan

The Committee recognises that there is an unusually diverse and encompassing set of conservation and research instruments, guidelines and plans already in place for the koala across its entire range, in individual states, and for some regional populations. However, there is no existing overarching conservation strategy for the entity "koala populations occurring in Queensland, New South Wales and the Australian Capital Territory". This gap may inhibit the development and implementation of the most targeted conservation actions for this entity and constrain coordination of conservation effort across relevant agencies and interest groups.

Furthermore, notwithstanding the considerable existing array of conservation initiatives and plans, the koala's conservation outlook continues to decline, demonstrating *ipso facto* the insufficiency of those existing instruments, and the need to revise them, re-focus them, or complement or replace them with new instruments. In addition, the Senate Inquiry provided numerous recommendations for further conservation management and research activities, additional to those currently included in existing plans; and the Inquiry described a series of shortcomings in the principal national conservation plan, the *National Koala Conservation and Management Strategy 2009-2014*. To some extent, that Strategy may inevitably be sub-optimal, given that it must frame management actions relating to over-population in some regions and to rapidly declining populations in other regions. A conservation or recovery plan that focuses only on those populations in most peril will deliver better conservation outcomes.

Accordingly, the Committee recommends that a recovery plan be developed for the entity "koala populations occurring in Queensland, New South Wales and the Australian Capital Territory". Particular circumstances of the koala's case have impressed the Committee with the need for suggesting here some guidelines around the development of such a recovery plan. The Committee considers that development of such a plan requires careful contextualisation, in particular with reference to:

- The time frame. Most recovery plans span 5 or 10 years. The information considered by the Committee indicates that the koala is affected by processes occurring over longer time periods (notably including the likelihood that climate change may make much of its inland range uninhabitable over the next 20-50 years, and that current development pressures are likely to result in a spate of incremental local extinctions in coastal areas over comparable time frames).
- Policy implications. The koala's conservation problems epitomise landscape-scale management challenges, in particular about the extent of clearing and habitat connectivity, "extinction debt", concepts of sustainable development, and strategic regional planning. These issues are rarely (or typically ineffectively) dealt with in recovery plans for individual species probably because they are considered "higher-order" policy. For any recovery plan for the koala to be effective, there has to be meaningful engagement with such policy. A koala recovery plan offers the opportunity of an exemplar engagement of threatened species recovery with broader strategic planning and policy.
- Pre-emption. The koala faces many pressing conservation challenges. Most existing recovery plans perforce concentrate on such immediate issues. However, the Committee also recognises that koalas may become increasingly susceptible to a range of new and developing problems, particularly relating to disease and the consequences of limited genetic variability. A recovery plan with a long-term ambit should provide the framework for balancing immediate management responses with strategic planning for management of emerging problems.

Accordingly, the Committee recommends the development of a Recovery Plan for the "koala populations occurring in Queensland, New South Wales and the Australian Capital Territory", with such development framed to consider particularly the fundamental and challenging issues described above. Such a Recovery Plan should also include consideration of the set of recommendations provided by the Senate Inquiry. It should also include commitment to the development of integrated population assessment and monitoring across all regions (particularly those for which the current level of uncertainty about populations and their trends is greatest), the extent of post-drought recovery, and the extent to which current management interventions are having measurable success.

The Committee notes that careful consideration should be given to the relationship of this suggested Recovery Plan to that of the existing *National Koala Conservation and Management Strategy 2009-2014*. A Recovery Plan for the "koala populations occurring in Queensland, New South Wales and the Australian Capital Territory" should not obviate the need for a national koala management strategy, which should continue to provide a framework for the national integration of population monitoring, a mechanism for information exchange, a national reporting framework relating to the outcomes of management interventions, and an ongoing instrument for monitoring the conservation status of those koala populations not included in the Recovery Plan.

12. Recommendations

(i) The Committee recommends that the Minister declare the combined koala (*Phascolarctos cinereus*) populations in Queensland, New South Wales and the Australian Capital Territory to be a species for the purposes of the EPBC Act under s517 of the Act.

(ii) The Committee recommends that the list referred to in section 178 of the EPBC Act not be amended by including the koala (*Phascolarctos cinereus*) over its national extent.

(iii) The Committee recommends that the list referred to in section 178 of the EPBC Act be amended by **including** in the list in the **Vulnerable** category the combined koala (*Phascolarctos cinereus*) populations in Queensland, New South Wales and the Australian Capital Territory.

(iv) The Committee recommends that there should be a recovery plan for this species.

Threatened Species Scientific Committee

25 November 2011

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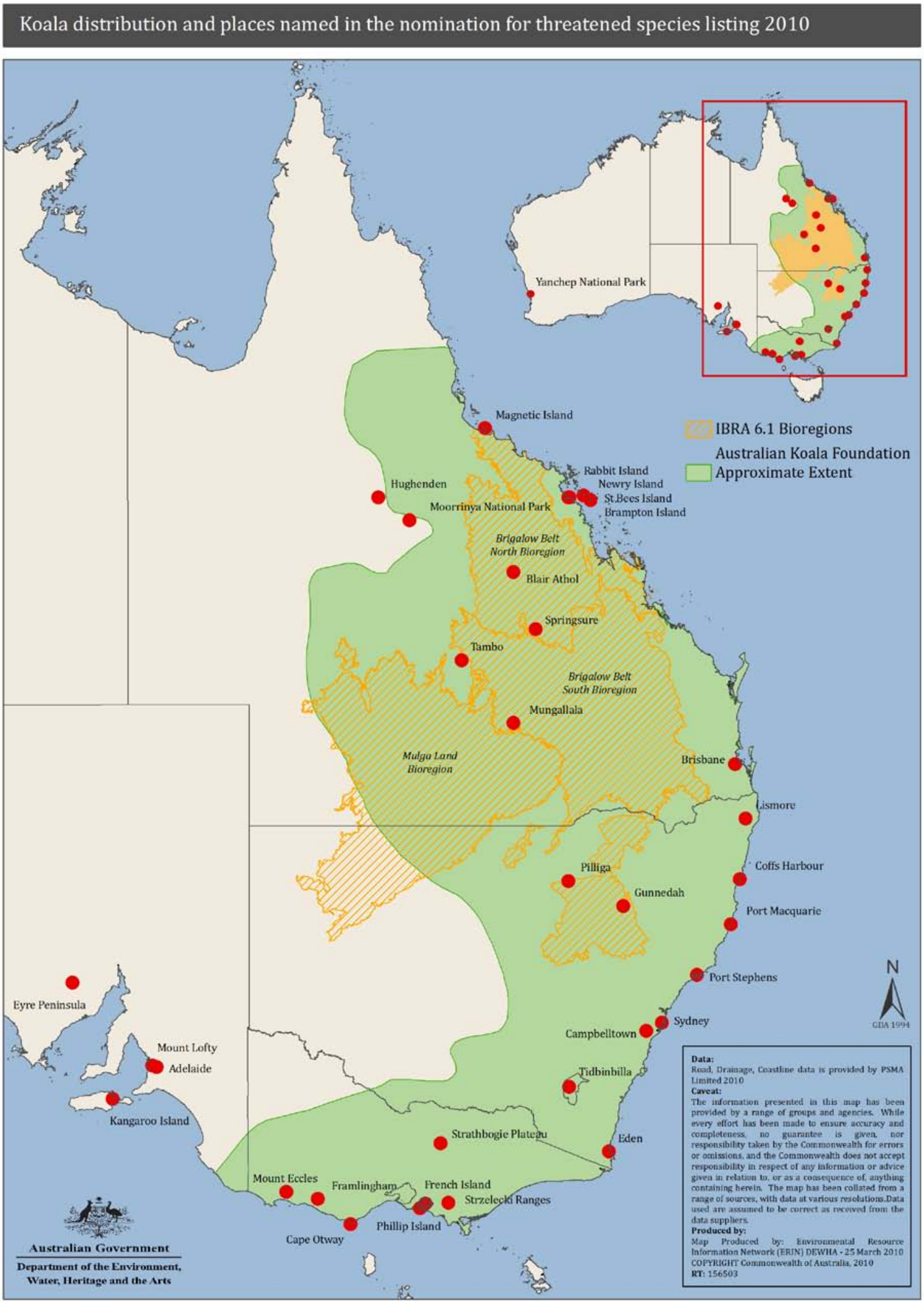

Figure 1. Distribution of the koala and places named in the text of the nomination for listing as a threatened species under the *Environment Protection and Biodiversity Conservation Act (1999).*