Australian Government
Department of Agriculture, Water and the Environment

Conservation Advice for *Phascolarctos cinereus* (Koala) combined populations of Queensland, New South Wales and the Australian Capital Territory

In effect under the *Environment Protection and Biodiversity Conservation Act 1999* from 12 February 2022.

This document combines the approved conservation advice and listing assessment for the species. It provides a foundation for conservation action and further planning.

Phascolarctos cinereus (Koala) © Copyright Karen Ford.

Contents

Conservation status

The *Phascolarctos cinereus* (Koala) combined populations of Queensland, New South Wales and the Australian Capital Territory were determined to be a species for the purposes of the *Environment Protection and Biodiversity Conservation Act 1999* (Cwth) (EPBC Act) (s517) on 27 April 2012 and listed in the Vulnerable category of the threatened species list under the EPBC Act effective from 2 May 2012. For conciseness, it is referred to hereafter as the listed population.

The listed population was reassessed in 2021 by the Threatened Species Scientific Committee to be eligible for listing as Endangered under criteria 1. The Committee's assessment is at Attachment A. The Committee's assessment of the listed population's eligibility against each of the listing criteria is:

- Criterion 1: A2C and A4C: Endangered
- Criterion 2: Ineligible
- Criterion 3: Ineligible
- Criterion 4: Ineligible
- Criterion 5: Insufficient data

Species can also be listed as threatened under state and territory legislation. For information on the current listing status of this species under relevant state or territory legislation, see the Species Profile and Threat Database.

Species information

Taxonomy

This species is conventionally accepted as *Phascolarctos cinereus* (Koala) (Goldfuss 1817). The koala is a single species whose physical appearance differs with latitude. Morphological differences include size, fur colouration and fur length. Three subspecies of koala were previously described on the basis of morphological differences in size and fur colouration: *Phascolarctos cinereus adustus* (Queensland) (Thomas 1923), *P. c. cinereus* (New South Wales) (Goldfuß & Bischof 1817) and *P. c. victor* (Victoria) (Troughton 1935). There is no genetic evidence to support these subspecies (Wedrowicz et al. 2017). A recent genomic assessment of population structure indicates spatially-organised genetic structure within the species (Kjeldsen et al. 2019), meaning that a large proportion of genetic variation can be attributed to the geographic distance between populations (Eldridge & Lott 2020).

The koala population was sub-divided in 2012 due to substantial differences in management and conservation status across the species range. Under section 517 of the EPBC Act the combined koala populations of Queensland, New South Wales and the Australian Capital Territory were declared to be a species for the purposes of the Act. This entity was listed as Vulnerable. The koala was not found to be eligible for listing at the national scale (SEWPaC 2012b).

Description

Names applied to the koala by different Indigenous language groups include: Guula and Gulawayn in the Gathang language, Barrandhang, Gurabaan, Naagun and Ginaagun from the Wiradjuri language, Borobi in the Yuambeh language, Doombearpee and Dumirripi in the Jandai language, and Goala from the Kabi language.

The koala is a medium-sized marsupial with a stocky body, large, rounded ears, sharp claws and variable but predominantly grey-coloured fur. Males are typically larger than females. Its morphological appearance changes gradually from south to north across its range, with larger individuals in the south and smaller individuals in the north. The average weight of males is 12 kg in Victoria compared with 6.5 kg in Queensland. In the south, the koala is characterised by longer, thicker, brown-grey fur, whereas in the north it has shorter, silver-grey fur (Martin & Handasyde 1999).

Distribution

The National distribution

The koala is a wide-ranging marsupial endemic to Australia. It typically occurs in eastern Australian forests and woodlands of predominantly *Eucalyptus* species. Its historical range extends over 22° of latitude and 18° of longitude (Martin & Handasyde 1999). The koala's distribution is not continuous across this range and it occurs in several subpopulations that are separated by cleared land or unsuitable habitat (Martin and Handasyde 1999; NSW DECC 2008). The koala's distribution includes Queensland, New South Wales, the Australian Capital Territory, Victoria and South Australia. The listed population of the koala has a wide but patchy distribution that spans the coastal and inland areas of Queensland north to the Herberton area, extending westwards into hotter and dryer semi-arid climates of central Queensland, New South Wales and the Australian Capital Territory.

Other populations, which are not listed as threatened under the EPBC Act, occur to the south, in Victoria and South Australia. The species is widespread in lowland and foothill eucalypt forests and woodlands across Victoria. Its distribution extends to the south-east corner of South Australia. A number of successful introductions have expanded the distribution in South Australia to locations including Kangaroo Island and mainland areas of the Adelaide Hills, Eyre Peninsular and sites along the Murray River.

The natural range of the koala is determined by specialist food, habitat and environmental requirements. Typically, this includes forests and woodlands dominated by *Eucalyptus* species (Melzer et al. 2000). The koala's home range (the area an individual needs to survive) is highly variable and dependant on life history stage, soil fertility, habitat quality and nutritional requirements. Consequently, home ranges across the species' distribution are highly variable, with home ranges in Queensland and New South Wales reported to vary between 3 and 500 ha (home range data summarised in: Wilmott 2020). Habitat suitability models indicate that koalas are best suited to locations where the mean maximum summer temperatures are 23-26^{o}C and mean annual rainfall ranges from 700 -1500 mm (Adams-Hosking et al. 2011). However, koalas can occur in more extreme environments at the limits of their natural range (McAlpine et al. 2015).

The koala's distribution and population size have declined significantly since European colonisation (Melzer et al. 2000; Sherwin et al. 2000). Much of the koala's national distribution

now overlaps with human-modified landscapes. Vegetation clearance from activities including urbanisation, grazing, agriculture and mining have significantly reduced the koala's distribution (McAlpine et al. 2015). Climate change drivers (e.g., drought and rising temperatures) have also resulted in a reduction in climatically suitable habitat (Adams-Hosking et al. 2011).

Concerns over the declining koala population in Queensland, New South Wales and the Australian Capital Territory resulted in the koala combined populations of Queensland, New South Wales and the Australian Capital Territory being listed as Vulnerable in 2012 under the EPBC Act (TSSC 2012). Historically, national and regional estimates of koala population size have been limited, fragmented and based on limited data (Melzer et al. 2000). This has made quantitative assessment of koala populations at the national level problematic. The 2012 listing highlighted the lack of peer-reviewed population data (TSSC 2012). In response to this data gap, in 2012, an expert elicitation estimated that the national koala population size was 329,000 (range: 144,000-605,000) (Adams-Hosking et al. 2016). It also indicated a 24 percent decline nationally over the preceding three koala generations (15-21 years). For the listed population in Queensland and New South Wales, the percentage loss was estimated at 53 percent and 26 percent respectively. No data were detailed for the Australian Capital Territory, however the earlier 2012 listing advice (TSSC 2012) suggested a high likelihood of the koala being present in the Australian Capital Territory, though with some populations originating from deliberate introductions from outside the Australian Capital Territory and possibly some natural populations.

For the listed population of koalas in Queensland, New South Wales and the Australian Capital Territory, extent of occurrence (EOO), the area encompassing all known occurrences of a species across its range (IUCN 2019), is estimated to be 1,665,850 km^2. This figure is based on the mapping of point records from a 20-year period (2000–2020) obtained from state governments, museums and CSIRO. The EOO was calculated using a minimum convex hull, based on the IUCN Red List Guidelines (DAWE, 2020). During the 2019-2020 bushfire season an estimated 9 percent (>36,800 km^2) of the koala's distribution was impacted by fire (DAWE 2021a). This agrees with estimates generated by the NESP Threatened Species Recovery Hub of 9-11.4 percent.

In contrast to the Queensland, New South Wales and Australian Capital Territory populations, koala populations in the southern part of the species' range, in Victoria and South Australia, are robust, and in some cases overpopulation has led to active population control measures being put in place (Menkhorst 2008). Despite historically suffering from population crashes and relocations, koala numbers are currently high in Victoria (Heard and Ramsey 2020) and mainland South Australia (DEW 2018), and those subpopulations are not listed.

Koala translocations have occurred in areas outside their natural range. These have resulted in establishment of new populations both in mainland areas (e.g. Adelaide Hills, Eyre Peninsula, Riverland) and on many islands in South Australia (Kangaroo Island), Victoria (French Island, Phillip Island, Raymond Island, Snake Island) and Queensland (Brampton Island, Magnetic Island, St Bees Island) (Melzer et al. 2000). Koalas have also been re-introduced to areas within their natural range in the Australian Capital Territory, New South Wales, mainland Victoria and the south-east of South Australia.

For the listed population in Queensland, New South Wales and the Australian Capital Territory, modelling of koala distribution indicates that in future it will be further constrained by climatic stressors (Adams-Hosking et al. 2011). In particular, shifts in summer temperatures, humidity and water availability pose a significant threat to the koala as a result of acute physiological stress during heatwaves, compounded by drought (Runge et al. 2021a). Forecasting models predict that a large area of koala habitat may be lost, accompanied by a large reduction in the koala population, under 2070 climate change projections (Adams-Hosking et al. 2011; Runge et al. 2021b). These losses will result in the southwards and eastwards contraction of suitable habitat across their range. Models indicate that koala occupancy is strongly dependant on annual rainfall and the distance to water features (Santika et al. 2014). Koalas may survive in refuge areas where microclimates such as deep gullies, caves, cliffs or dense vegetation provide refuge from heat, and perennial water results in leaf-water content remaining high (Runge et al. 2021a).

Distribution across the range of the EPBC Act listed koala population: Queensland, New South Wales and the Australian Capital Territory

Queensland distribution

Koalas are widespread across Queensland (map 1), occurring in patchy and often low-density populations across the different bioregions. They occur as far north as the Einasleigh Uplands and Wet Tropics bioregions with records to the south and west in the Desert Uplands, Central Mackay Coast, Mitchell Grass Downs, Mulga Lands, Brigalow Belt North, Brigalow Belt South, and South Eastern Queensland where they are most frequently sighted (Adams-Hosking et al. 2016). Koalas in Queensland inhabit the moist coastal forests, southern and central western subhumid woodlands, and a number of eucalypt woodlands adjacent to waterbodies in the semi-arid western parts of the state (Melzer et al. 2000). In many locations, koala populations are of low density, widespread and fragmented (Melzer et al. 2018). Surveys in north-western Queensland found that koalas were patchily distributed, associated with creek-lines, areas of higher tree species richness, with higher abundance correlating with leaf-moisture content (Munks et al. 1996).

State-wide estimates of population size are limited, with data and survey effort skewed towards south-east Queensland. In response to this, and the lack of peer reviewed estimates of koala numbers highlighted in the 2012 listing advice (SEWPaC 2012a; TSSC 2012), an expert elicitation exercise was undertaken in 2012 (Adams-Hosking et al. 2016). The data from this expert elicitation are now widely recognised as the most accurate baseline for koala population numbers across the bioregions, states and territories (e.g., NSW Government 2020; Dissanayake et al. 2021) and therefore supersede the 2012 listing data. These data provide a reference point for this Conservation Advice. In 2012, this expert elicitation estimated that that there were 79,264 koalas in Queensland distributed across 8 bioregional areas (Adams-Hosking et al. 2016). The highest population estimates were reported for three bioregions: Brigalow Belt North (15,179), Mulga Lands (15,286) and South East Queensland (15,821). The other bioregions with koalas present included Central Mackay Coast (8857), Desert Uplands (6357), Einasleigh Uplands and Wet Tropics (4750), Mitchell Grass Downs (1943), South Brigalow (11,071). In 2012, it was estimated that Queensland's koala populations had declined over the three preceding generations (15 to 21 years) by an average of 53 percent (Adams-Hosking et al. 2016).

The eight Queensland bioregions with koalas cover a total area of 1,489,650 km^2. This represents a mean density of 0.0005 koalas/ha across the 8 bioregions in Queensland based on 2012 population estimates. Across the state, South East Queensland has the most comprehensive dataset, reflecting higher survey effort. Based on 2012 population estimates (Adams-Hosking et al. 2016), the bioregions with the highest density of koalas in Queensland included the Central Mackay Coast (0.006 koalas/ha) and South East Queensland (0.002 koalas/ha). Both these bioregions were impacted by bushfire in the 2019-2020 bushfires. In 2021, within the eight Queensland bioregions, an estimated 13 percent (194,021 km^2) of land area overlapped with the koala species distribution model (DAWE 2021a). Of this, 1,931 km^2 of modelled likely koala distribution burnt across the state in the 2019-20 bushfires, representing a total 1 percent of modelled likely koala distribution (DAWE 2021a). Four bioregions were impacted by fire: South East Queensland (2 percent burnt), Central MacKay Coast (2 percent), Brigalow Belt South (1 percent burnt), and New England Tablelands (1 percent). Modelling of future climate-suitable koala distribution indicates a further contraction of 17 to 78 percent by 2030 from the 2011 baseline as a direct result of climate change (Adams-Hosking et al. 2011; Adams-Hosking et al. 2016). The bioregions predicted to be most heavily impacted by climate change included the Mulga Lands (100 percent of climatically suitable koala habitat lost by 2030), the Desert Uplands (100 percent loss by 2030) and the Central Mackay Coast (57 to 96 percent loss by 2030).

New South Wales distribution

Koalas in New South Wales occur from the northern border with Queensland. The northern NSW distribution includes the Mulga Lands, Darling Riverine Plains, Brigalow Belt South, Nandewar, New England Tablelands, and South East Queensland (NSW Section) bioregions. Koalas also occur within the eastern coastline bioregions of the NSW North Coast, Sydney Basin and South East Corner at the border with Victoria. Their western distribution extends into the South-Eastern Highlands, NSW South Western Slopes, Cobar Peneplain, Riverina, and Murray Darling Depression bioregions (Map 1). Koalas occupy a wide range of habitats (NSW Government 2019b, a). The majority of koalas in New South Wales are found in forests and subhumid woodlands on the central and north coast , and to the west across the Western Plains and slopes, within Pilliga forest, low woodland and forested areas (TSSC 2012; Adams-Hosking et al. 2016). Low-density populations also occur west of the Great Dividing Range in semi-arid environments. Habitat in these areas is fragmented and this has resulted in a patchy distribution of koalas across their range with significant numbers occurring on privately owned land (Melzer et al. 2000; Lunney et al. 2009; TSSC 2012). Modelling of koala habitat in New South Wales suggests climate-suitable habitat will contract by 8 to 19 percent by 2030 from the 2011 baseline as a direct result of climate change (Adams-Hosking et al. 2011; Adams-Hosking et al. 2016). Koala distribution has shrunk across NSW, with declines documented from the eastern coastal bioregions to the western populations (Predavec et al. 2018). These declines have been driven by habitat loss, temperature increase and drought (Lunney et al. 2014; Santika et al. 2015). Extinction risk is predicted to be greater in western NSW than in the east under future scenarios of climate and land use change (Santika et al. 2014). Predicted changes in the near (2030) and more distant (2070) future include increased maximum temperatures, reduced minimum temperatures, more extremely hot days (where maximum temperature > 35^{o}C), shifting rainfall patterns, and an increase in average fire weather days. Modelling indicates that by 2070 the habitat losses will be severe (NSW Government 2014).

In 2012, the mean population estimates for koalas within bioregions indicated that the highest numbers of individuals occurred in the bioregions of South Brigalow and Nandewar (11,133), NSW North Coast (8,367) and the Sydney Basin (5,667) (Adams-Hosking et al. 2016). Other bioregions had smaller, but significant koala populations (<3,000 individuals): Murray-Darling Depression (55), South East corner (655), Cobar Peneplain and Riverina (2,354), Darling-Riverine Plains (9,964), Mulga Lands (711), New England Tablelands (2,771), NSW Southwestern Slopes (2,310), South-Eastern Highlands (1363). This study concluded that the NSW koala population had declined by over 26 percent in the preceding (and potentially future) three koala generations (Adams-Hosking et al. 2016).

In 2018, the NSW Framework for the spatial prioritisation of koala conservation actions (Rennison & Fisher 2018) concluded that both the expert elicitation data (Adams-Hosking et al. 2016) and the available records trend data indicated a significant decline in koalas across the state in recent years. The only bioregion to have convincing evidence of a stable population was the New England Tablelands. Since this framework was developed, this bioregion has been impacted by bushfire (see below).

Across the 15 bioregions in NSW containing koalas, nine were impacted by the 2019-20 bushfires with a total of 34,666 km^2 burnt (DAWE 2021). The bioregions most heavily impacted by fire included the South East Corner (52 percent burnt), the Sydney Basin (30 percent burnt) and NSW North Coast (30 percent burnt). Other bioregions that contain koalas and were significantly burnt are: South Eastern Queensland (NSW section) (19 percent burnt), South Eastern Highlands (13 percent burnt), New England Tablelands (13 percent burnt), Australian Alps (4 percent burnt), Nandewar (4 percent burnt), and NSW South Western Slopes (2 percent burnt). Koalas have displayed nuanced responses to fire with significant declines in numbers following high severity fire but little change in occupancy or density following low severity fire (NSW Government 2021a). Further research is required to understand how fire impacted koalas across the different bioregions.

The Australian Capital Territory distribution

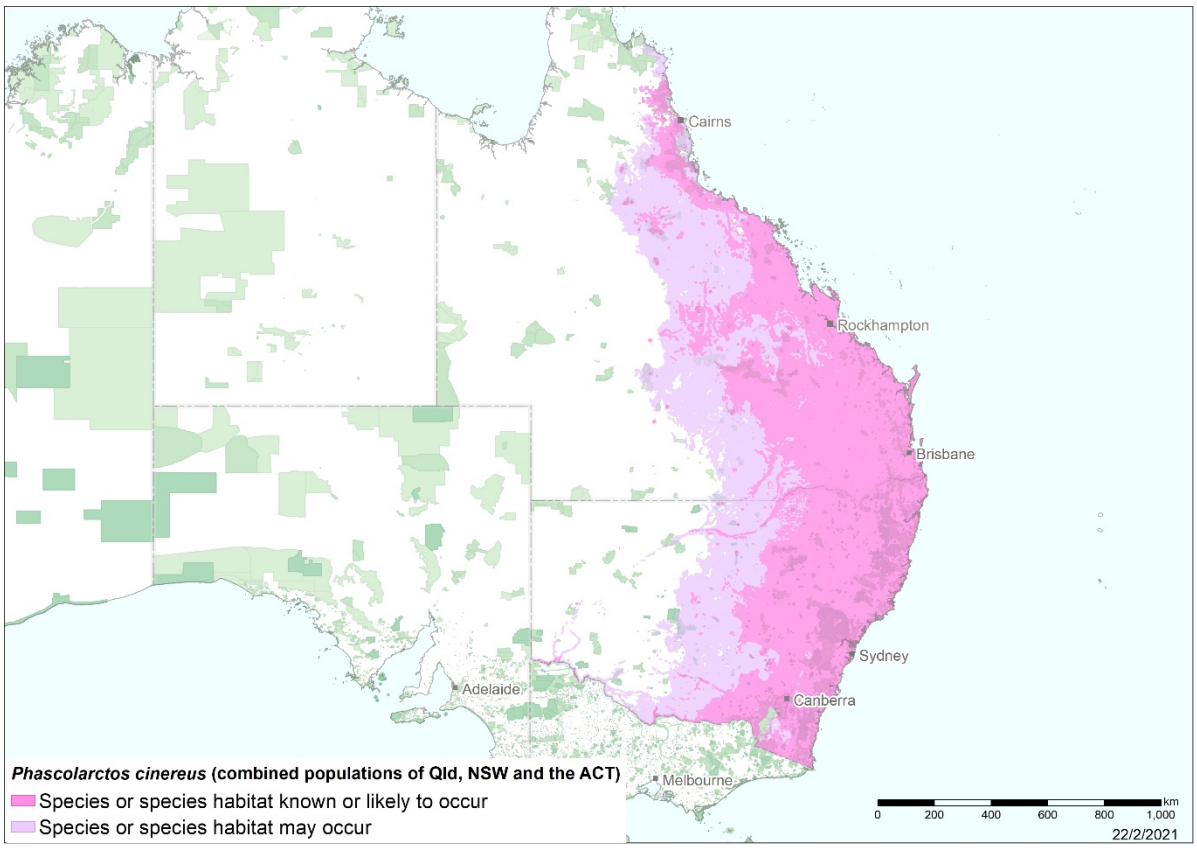
Koalas have historically occurred in the Australian Capital Territory. In 2009, it was suggested that small koala populations were historically present in the Tidbinbilla and Brindabella Ranges, around Bushfold, the Orroral Valley and Namadji National Park (TSSC 2012). These populations were thought to be the result of deliberate introductions as well as remnant, natural koala populations. In the 2012 expert elicitation process the Australian Capital Territory was not considered separately and Australian Capital Territory data were aggregated into NSW estimates (Adams-Hosking et al. 2016).

There have been limited reports of koalas in the Australian Capital Territory along the border with New South Wales. In May 2021 a solitary koala was observed over several days in Oaks Estate near the Molonglo River (K Ford, 2021 pers com May 11). In 2014 a koala was observed crossing the highway close to Defence land, near Canberra airport (Fitzgerald 2014). There are also historic records in the 1980s of koalas on the western borders of the Australian Capital Territory and it was suggested that these were animals dispersing from Brindabella. A koala survey in 2018 was conducted in areas considered to be likely koala habitat and no koalas were recorded (Capital-Ecology 2018). The site selection was based on ACT koala survey guidelines. However, thirteen hard-to-access monitoring sites, which included seven sites in Namadgi National Park, plus an additional fifteen Commonwealth owned Defence sites were not included

in the survey. The report recommended that acoustic surveys be conducted in the breeding season to confirm these findings (Capital-Ecology 2018). Currently there are no known resident koala populations and koala surveys are not routinely conducted in the Australian Capital Territory.

The bioregions which contain koala habitat in the Australian Capital Territory include large areas that have been impacted by bushfire. In particular, the Orroral Valley, a location where koalas have historically been observed, burnt in 2003 and again in 2019-2020. In the 2019-20 bushfires, an estimated 23 percent (211 km^2) of koala habitat burned (DAWE 2021a). Koala habitat occurs in two bioregions in the Australian Capital Territory, the Australian Alps and South Eastern Highlands, of which 57 percent (102 km^2) and 15 percent (109 km^2) respectively of the total area burnt in recent bushfires. Modelling suggests climatically suitable koala habitat in the Australian Capital Territory will contract by 10 percent by 2030 from the 2011 baseline as a direct result of climate change (Adams-Hosking et al. 2011; Adams-Hosking et al. 2016).

Map 1 Modelled species distribution of the listed koala in Queensland, New South Wales and the Australian Capital Territory. Note that the listed koala distribution does not include Victoria or South Australia.



Source: Draft base map Geoscience Australia; species distribution data Species of National Environmental Significance database. The 2021 SDM was modelled using Maxent, with the harmonised habitat mapping subsequently incorporated (Runge et al. 2021b).

Caveat: The information presented in this map has been provided by a range of groups and agencies. While every effort has been made to ensure accuracy and completeness, no guarantee is given, nor responsibility taken by the Commonwealth for errors or omissions, and the Commonwealth does not accept responsibility in respect of any information or advice given in relation to, or as a consequence of, anything containing herein.

Species distribution mapping: The species distribution mapping categories are indicative only and aim to capture a) the specific habitat type or geographic feature that represents the recent observed locations of the species (known to occur), b) the suitable or preferred habitat occurring in close proximity to these locations (likely to occur); and c) the broad environmental envelope or geographic region that encompasses all areas that could provide habitat for the species (may occur). These presence categories are created using an extensive database of species observation records, national and regional-scale environmental data, environmental modelling techniques and documented scientific research.

Cultural and community significance

Koalas are culturally significant for many Indigenous peoples across south-eastern and eastern Australia. They hold a significant and diverse role in many Indigenous cultural practices and belief systems. The koala's name has many interpretations within the different Indigenous languages. The word koala may be a loan word derived from *gula* or *gulawan* from the Dharuk language of the Sydney region (Cahir et al. 2020). Early western spellings also include "coola" and koolah". The name "Koala" may also reflect the fact that koalas rarely or never drink free water. Other local Indigenous names such as "*kaola*" translate as "no drink". Several Indigenous narratives describe the koala as the giver or taker of water (Cahir et al. 2020).

The cultural and community significance of the koala is specific and unique to different Indigenous language groups. In New South Wales, koalas are prominent in creation stories and narratives and are known to be totemic for different language groups (Cahir et al. 2020). They are depicted in rock art and were hunted for meat prior to the arrival of colonists. The skins of the koala were used to make rugs by the Gumbaynggirr peoples, while Elders in the Goulburn Plains region used koala fur in initiation ceremonies (Cahir et al. 2020). In Queensland, their spiritual significance can be linked to epic creation stories while in certain regions koalas were hunted for their skin and fur (Cahir et al. 2021). In Victoria, koalas also have a utilitarian and symbolic significance being a revered animal. Records from the region suggest that in some areas they were traditionally used for food but not for skins or fur (Schlagloth et al. 2018). The historic relationship between Aboriginal communities and koalas across the listed range highlights the importance of consulting with Aboriginal communities when planning and undertaking koala focused conservation activities (Cahir et al. 2021).

The koala forms an integral part of modern Australian identity. From the first colonial exhibits in 1861 at the Melbourne Zoo to today, it has become a national icon that is recognised internationally as a symbol of Australia (Markwell 2020a, b). The koala is depicted widely in art, children's books, television shows and popular culture. Many celebrities opt to be photographed with koalas and they have been used widely in marketing campaigns (e.g., Qantas Airlines from 1967 to 1992) (Markwell 2020b). While considered by many Australians as an intrinsically valuable component of Australian fauna, the koala also contributes significantly to tourism.

Relevant biology and ecology

Female koalas reach sexual maturity between 2 and 3 years of age (McLean & Handasyde 2007) and may then produce one offspring per year. Females have a 12-month lactation period and young koalas are weaned after this period. Weaning coincides with periods of high food availability and favourable climatic conditions. This ensures the best survival conditions for offspring approaching independence (Ballantyne et al. 2015). Local factors, including population density, food quality and availability, soil type and climate, influence the timing of breeding (McLean & Handasyde 2007; Ballantyne et al. 2015). Koalas may not breed every year if conditions are unfavourable, and breeding can be unsuccessful due to poor body condition or disease (e.g. *Chlamydia*) (McLean & Handasyde 2007).

Koala reproduction is heavily influenced by seasonality, and the breeding season differs between northern and southern populations. In the north, an estimated 60 percent of births occur in summer and early autumn (December-March), and the remainder are distributed throughout the year (Ellis et al. 2010a). The trigger for this increase in birth rate is not known but does coincide with periods of peak rainfall in Queensland. It has been suggested that opportunistic breeding occurs when food availability increases as a response to rainfall (Ellis et al. 2010a). In locations where rainfall is less seasonally variable, joeys are produced at any time of the year. In South Australia, the ratio of male to female births has also been shown to vary with half of male births occurring before the end of November. In contrast, 50 percent of female births do not occur until the end of December (McLean & Handasyde 2007). One explanation for this is that females in good condition, with greater resource availability, produce larger, healthier male offspring due to an increased period of maternal investment. Studies report no evidence of sex ratio differences in the timing of births, or the size of joeys in Queensland (Ellis et al. 2010a).

In the wild, longevity is more than 15 years for females and more than 12 years for males (Martin & Handasyde 1999). Generation length is defined here as: "*the average age of parents of the current cohort (i.e., newborn individuals in the population)*" (IUCN 2019). The generation length of the listed koala is therefore estimated to be 6 to 8 years. This is also consistent with other assessments (Phillips 2000; TSSC 2012; Woinarski 2020).

Koalas are tree-dwelling, obligate folivores (leaf eaters) with a highly specialised diet. The koala's diet is defined by the availability and palatability of a limited variety of *Eucalyptus*, *Corymbia* and *Angophora* species. Koalas are nocturnal and spend significant periods of time moving across the ground between food and shelter trees. Movement increases in the breeding season (typically September to February) (Melzer & Tucker 2011). Koalas are reported to utilise more than 400 different species of tree for their food and habitat requirements with different tree species varying by habitat type and location across their range. Primary food species differ across habitats and may be as few as two at a particular location (Melzer et al. 2000; Tucker et al. 2008; Kjeldsen et al. 2019). Koala browsing preferences show regional differences which are influenced by the chemical profiles and water content of different target food leaves. There is both intra- and inter-species variability in the palatability and nutritional value of the leaves of their preferred food trees (Stalenberg et al. 2014). Their specialist dietary requirements determine their potential habitat and range distributions (Moore & Foley 2005; Moore et al. 2010).

Habitat critical to the survival

Koala habitat includes both coastal and inland areas that are typically characterised by Eucalyptus forests and woodlands. The wide-ranging distribution of the koala has resulted in a diverse range of habitat associations across different bioregions, influenced by local climate, topographical and landscape associations. Biophysical habitat attributes for the koala include places that contain the resources necessary for individual foraging, survival (including predator avoidance), growth, reproduction and movement. The total amount of resources (including habitat attributes) and how they are arranged in the landscape influence the viability of metapopulations and processes.

For an individual koala, these resources include access to sufficient quality food and shelter trees to meet their daily energetic requirements and reproductive needs, and a place to avoid

predators. This includes forests or woodlands, road-side and rail vegetation and paddock trees, safe intervening ground matrix for travelling between trees and patches to forage and shelter and reproduce and access to vegetated corridors or paddock trees to facilitate movement between patches. These resources fall within individual koala's home ranges and allow for interaction with adjacent individuals.

A population of koalas requires a sufficient total amount of resources within their habitat of adequate quality to support a viable biological population where mortality, survival, and recruitment are balanced or recruitment increasing to optimal carrying capacity and within the bounds of natural fluctuations. Crucial habitat elements include patches and corridors for gene flow. Over longer-time frames habitat critical includes climate refugia such as drainage lines, riparian zones and patches that are resilient to drying conditions due to favourable hydrological systems. Additionally, it includes areas that may be temporarily unoccupied, because of seral (maturity or time) changes to habitat quality that arise through processes such as fire, drought, timber harvesting or disease (shifting habitat mosaic) or degradation and are available for future recolonisation.

Habitat critical to the survival of a species is defined as: the areas that the species relies on to avoid or halt decline and promote the recovery of the species. Under the EPBC Act, the following factors and any other relevant factors may be considered when identifying habitat that is critical to the survival of a species:

(a) whether the habitat is used during periods of stress (examples: flood, drought or fire);

(b) whether the habitat is used to meet essential life cycle requirements (examples: foraging, breeding, nesting, roosting, social behaviour patterns or seed dispersal processes);

(c) the extent to which the habitat is used by important populations;

(d) whether the habitat is necessary to maintain genetic diversity and long-term evolutionary development;

(e) whether the habitat is necessary for use as corridors to allow the species to move freely between sites used to meet essential life cycle requirements;

(f) whether the habitat is necessary to ensure the long-term future of the species or ecological community through reintroduction or re-colonisation;

(g) any other way in which habitat may be critical to the survival of a listed threatened species or a listed threatened ecological community.

Such areas, if identified, would be expected to include habitat occupied and habitat currently unoccupied, areas necessary for population processes and maintenance of genetic diversity and evolutionary potential, and areas required to accommodate future population increase, recolonisation, reintroduction, or as climate refugia.

The information set out in this conservation advice relating to the functional ecology of the koala and its habitat are likely to form the basis of habitat critical to the survival of the koala. Having regard to the above factors and other relevant factors at the time of completing this document, it is not practicable to identify by description and to provide spatial information on

the habitat critical to the survival of the koala. This is because there is insufficient knowledge and data to unambiguously identify and spatially delineate habitat critical to the survival of the koala. A National Koala Monitoring Program was established in 2021 in response to these critical data requirements.

This document provides general guidance for habitat critical to the survival of the listed koala. The EPBC Act referral guidelines are available for potential proponents to navigate the complexity of koala habitat to identify significant impacts (DofE 2014). The guidelines provide guidance on important requirements, survey planning, and standards for mitigation impacts in context of long-term recovery planning for the listed koala.

Important populations

In this section, the word population is used to refer to subpopulation, in keeping with the terminology used in the EPBC Act and state/territory environmental legislation.

Important populations are defined as those that are valued for cultural, social, and economic reasons as well as for the species conservation.

i) For conservation of the listed koala, among other reasons, it will be imperative to maintain populations that:

- have the potential to act as source populations to adjacent areas of suitable, or potentially suitable, habitat;
- exist in areas of climatically suitable refugia during periods of environmental stress including droughts, heatwaves, and long-term climate change;
- are genetically diverse;
- are disease free and/or exhibit low rates of infection with important pathogens;
- contain genes which may confer adaptation to current and future environmental stressors;
- are geographical or environmental outliers within the species range.

ii) Populations are also valued for social, cultural or economic reasons, and may or may not, overlap with populations listed above. Reasons may include, but not limited to:

- cultural and spiritual importance to Indigenous people;
- the social value and enjoyment of having koalas close to residential areas;
- the economic value brought to local business and tourism;
- the iconic species value at the national and international political and community level.

State level important populations

At the state and territory level, New South Wales has identified critical koala populations as "areas of currently known high koala occupancy" (DPIE 2020). Queensland has identified priority areas for management actions to achieve the highest likelihood of conservation outcomes for koalas in South East Queensland. This has included prioritising koalas located in high quality habitat with a high likelihood of successful threat management (DES 2020). Current efforts to assess and identify important populations across the range are hindered by a lack of

comprehensive, unbiased data (DPIE 2020; DAWE 2021b) with the majority of study effort focusing on high density koala populations in easily accessible locations. The 2021 National koala Monitoring Program will address these critical data gaps. Examples of important populations are detailed below.

Genetically important populations

Four spatially distinct, genetic koala management units have been identified nationally (Johnson et al. 2018; Eldridge & Lott 2020). These important genetic populations include: 1) Queensland and New South Wales populations north of the Clarence River Valley, New South Wales; 2) south of the Clarence River Valley, New South Wales to north of the Sydney Basin; 3) south of the Sydney Basin to approximately the New South Wales /Victorian boarder; and 4) Victoria and South Australia populations. Work on the genetic values of different populations is still in its infancy and research is ongoing.

Climate sensitive populations

Koalas at the western edge of their range are being impacted by shifts in rainfall patterns and increasing frequency of drought and heat stress resulting directly from climate change (Adams-Hosking et al. 2011; Davies et al. 2013; Runge et al. 2021b). The recent national workshop of koala monitoring experts (DAWE 2021b) identified the koala subpopulations at the western edges of Queensland and New South Wales distributions (western edge populations) as a priority for immediate climate-related risk management and conservation efforts. The western edge populations are characterised by low koala densities and a high level of isolation from other populations, as a result of which they are increasingly vulnerable to environmental change and habitat loss. The western-edge populations were identified as potentially containing adaptive genes to environmental stressors indicating they have high conservation value (K Handasyde 2021, pers comm 9 February). The workshop recommendations included: an urgent need for population and ecological data (e.g. fertility rates, longevity, movement patterns, habitat requirements, thermal ecology); research into heat tolerance; action to protect these populations as they may prove critical to New South Wales and Queensland in the future; and consideration of translocation of individuals from these genetically important reservoir population to create an insurance population that could prove critical to future management.

Other important populations

Populations that have the potential to act as source populations for adjacent areas of suitable habitat and/or potentially suitable habitat. This includes climate-robust populations, large populations that exist in contiguous habitats, and populations that may link two larger populations.

Threats

The koala is threatened by wide-scale climate change drivers which include the increased frequency and intensity of drought and high temperatures, the increasing prevalence of weather conditions which promote bushfire, and a shrinking climatically suitable area (Adams-Hosking et al. 2011; McAlpine et al. 2015; Runge et al. 2021a). Simultaneously, koala populations are also being impacted by diseases, specifically koala retrovirus (KoRV) and Chlamydia (*Chlamydia pecorum*), human-related activities including habitat loss resulting from land clearance and mining, and mortality due to encounters with vehicles and dogs. These threats can also act synergistically. For example, habitat clearance and climate change drivers are associated with increased levels of physiological stress in wild koala populations (Narayan 2019). This in turn

can increase the incidence and impact of localised threats arising from encounter mortality with dogs and vehicles, disease, and food shortages (Narayan 2019).

Table 1 Threats impacting the koala

Threat	Status and severity [a]	Evidence
Climate change driven processes and drivers		
Loss of climatically suitable habitat	• Status: current and future • Confidence: known • Consequence: severe • Trend: increasing • Extent: across the entire range	Areas that are climatically suitable for koalas are contracting (Adams-Hosking et al. 2011). Climate change predictions indicate drier, warmer conditions across the koala's range. Current and future climate change projections indicate a progressive eastward and southwards contraction in the koala's suitable climate envelope and consequent suitable habitat (Adams-Hosking et al. 2011). Modelled climatic suitability from 2010 to 2030 indicates a 38-52% reduction for the listed population (Adams-Hosking et al. 2011), and forecast a 62% decline in koala habitat by 2070. This represents a 79% loss in Queensland and 31% loss in New South Wales (Runge et al. 2021a). The effects of climate change may play out through increased mortality associated with heat wave events and droughts, declines in reproduction rates associated with changes in food quality and availability, changes to movement patterns, exposure to diseases and other factors, as well as effects of climate change on fire regimes (see below for further details on these mechanisms).
Increased intensity/frequency of drought	• Status: historical, current and future • Confidence: known • Consequence: severe • Trend: increasing • Extent: across part of its range	Over the last 21 years, South East Australia has experienced two of its worst droughts in the historical record: the Millennium Drought (2000-2009) and the Big Dry (2017-2019). Low rainfall has been linked with physiological stress to koalas due to low moisture levels, causing negative effects on population viability (Davies et al. 2013). These periods of abnormally low rainfall, particularly in the west, have been associated with the decline, and in some cases, the crash of koala populations, forcing population contraction to critical riparian areas in some areas (Seabrook et al. 2011; DPIE 2020). In extreme cases, e.g., Springsure in Central Queensland, the areas worst affected by drought were along creeks where extensive

Threat	Status and severity [a]	Evidence
		tree death (die back) occurred and negatively impacted koala populations (Ellis et al. 2010b). In the future, average winter and spring rainfall are predicted to continue to decline across the koala's range (BoM 2021a). By the late twenty-first century, the frequency of moderate, severe, extreme and exceptional terrestrial water storage droughts is projected to increase substantially due to a reduction in the frequency of near-normal and wet conditions in Australia (Pokhrel et al. 2021). Cumulative frequency of droughts across the koala range are projected to increase by 30% by 2100 under RCP6.0 (the climate pathway we are on) (NOAA 2021). The frequency of severe and extreme droughts (Drought Severity Index >-1.6) will increase from 2.7% to 19.5%. This suggests that koala habitat will be in drought half the time, and severe drought every 5 years, on average. This is an increase from the currently observed frequency of drought every 5 years and severe drought every 30 years. Droughts also interact with threats posed by inappropriate fire regimes.
Increased intensity/frequency of heatwaves	• Status: historical/current/future • Confidence: known • Consequence: severe • Trend: increasing • Extent: across the entire range	Heatwaves can be defined as ≥ 3 consecutive days of unusually high night-time and day-time temperature (BoM 2021b). Due to climate change, average temperatures across the koala's range will continue to increase across all seasons resulting in an increased frequency and intensity of heat stress days and heat wave episodes (BoM 2021a). Heat stress threats will synergistically interact with drought, further exacerbating the impacts of reduced water availability. During periods of extreme heat stress koalas are also known to stop eating and starve to death (K Youngentob, pers comm 22/3/21).
Increased intensity/frequency of bushfire	• Status: historical/current/future • Confidence: known • Consequence: severe • Trend: increasing • Extent: across part of its range	During the summer of 2019-2020, > 3.5 million ha of koala habitat burnt across Queensland, New South Wales and the Australian Capital Territory (DAWE 2021a). Recent estimates suggest a population decline of 10% (or as much as 17%, with 80% confidence) one year after the 2019-20 bushfires. Of this, a decline of 7.1% was directly caused by bushfires, the remaining 2.3%

Threat	Status and severity [a]	Evidence
		decline was due to ongoing and antecedent threats (Legge et al. 2021). The future legacy of the 2019-2020 bushfires, assuming no future extreme events over three generations (2021-2042), indicates a population decline of 3.9% caused by the fires; a further population decline of 21.9% is attributed to antecedent and ongoing threats (Legge et al. 2021). Koala monitoring records from north-east New South Wales following the 2019/2020 bushfires, indicate that sites characterised by high-severity fire (e.g., canopy scorch) had zero koala occupancy (i.e., zero return/recovery) immediately post fire. At sites where koalas have been detected following fire, refuge areas were present in the surrounding landscape, or fire severity was lower (NSW Government 2021b). While koala's have returned to bushfire impacted locations it is likely to take many years before populations are fully re-established. Australia will continue to experience a harsher fire-weather climate into the future (BoM 2019, 2021a). The fire season length is increasing and the number of catastrophic fire days will increase in the future by an estimated 15-70% by 2050 (Climate-Council 2019). A broad range of fire-related threats exist. These include high frequency fire, high severity fire, shifts in fire season, biodiversity loss, declining ecological mechanisms, shifts in biotic interactions including reproduction and fire-predator interactions, fire-drought interactions, fire-fragmentation interactions which can be amplified by land clearing and logging, fire-climate feedback (see above) (Bradshaw et al. 2018; Leavesley et al. 2020). All of these threats will have a significant impact on koala habitat and resident populations.

Threat	Status and severity [a]	Evidence
Declining nutritional value of foliage	• Status: historical/current/future • Confidence: suspected/known • Consequence: severe • Trend: increasing • Extent: across part of its range	In-situ carbon dioxide (CO_2) manipulation experiments on *Eucalyptus tereticornis* and *E. amplifolia* found elevated CO_2 levels caused total nitrogen to decline in young eucalyptus leaves (Wujeska-Klause et al. 2019). However, increases in environmental temperature (eT), that will occur in parallel with elevated CO_2 in the future, were not included in open air experiments and green house experiments suggest eT may compensate completely for the negative impacts of CO_2 on leaf nitrogen in the future (DeGabriel et al. 2009; Robinson et al. 2012). Although elevated CO_2 can influence the production of some plant secondary metabolites such as tannins that may also impact the digestibility of leaves, the evidence for this in eucalypts is equivocal and further research is needed. Additional research is required to assess how elevated levels of CO_2 affect nitrogen and available nitrogen (which integrates the effects of tannins) (DeGabriel et al. 2009). Bushfire effects on the nutritional value of eucalypt regrowth (e.g., epicormic growth) are unknown and research has been initiated. Physical disturbance (e.g., logging during forestry activities and/or fire) alters tree species composition and can favour tree species that do not support the koala's nutritional requirements (Au et al. 2019).
Human related activities		
Clearing and degradation of koala habitat	• Status: historical, current and future • Confidence: known • Consequence: severe • Trend: increasing • Extent: across the entire range	Human activities (e.g., deforestation and land clearance for grazing, agriculture, urbanisation, timber harvesting, mining and other activities) have resulted in habitat loss, fragmentation and degradation. Over 10,000 km^2 of forest and woodland within the koala's range was cleared between 2000 and 2017 (Ward et al. 2019). The modelled koala distribution was revised in 2021 and the estimate of habitat loss would be expected to be higher if calculated using the new understanding of koala distribution. Clearing for grazing during this period was the major driver of loss of koala habitat, accounting for most of

Threat	Status and severity [a]	Evidence
		the deforestation within koala distribution (McAlpine et al. 2015; Evans 2016). Clearing for grazing has occurred across the range of the koala. Large areas of woodland have been lost since 2000 in western parts of the species range, including the Brigalow Belt, Mulga Lands, Darling Riverine Plains, Einasleigh Uplands and Desert uplands (Ward et al. 2019). These bioregions are home to large koala populations (Adams-Hosking et al. 2016). Most clearing has occurred on freehold or leasehold land (Ward et al. 2019). Land clearing continues to impact habitat across the koala's range (DES 2018). Clearing for mining and urbanisation has had localised impacts on the koala (Evans 2016; Ward et al. 2019). Urban expansion is concentrated along the eastern seaboard fringe of Queensland and NSW (Clark & Johnston 2016), which is also a stronghold of the koala. Low density and peri-urban development are expanding into forested and agricultural landscapes in these areas, while clearing for agriculture continues to occur across the koala's distribution. The expanding coal and coal seam gas developments of the past two decades and recent clearing for renewable energy projects represent additional but localised impacts to koalas (McAlpine et al. 2015). Land-use decisions affecting koalas have been influenced, both positively and negatively, by the policy environment and social attitudes around land-clearing (Heagney et al. 2021; Simmons et al. 2021).
Encounter mortality with vehicles and dogs	• Status: historical/current/future • Confidence: known • Consequence: severe • Trend: increasing • Extent: across part of its range	Vehicle related mortality occurs regularly on roads in close proximity to occupied koala habitat (Gonzalez-Astudillo 2018; Queensland-Government 2021). Dog attacks are also a significant cause of death and injury especially in areas within and adjacent to peri-urban and residential areas (DPIE 2020). Koalas are unable to adapt to these threats and as human activities continue to expand into koala habitat, trauma from these threats will continue. A large proportion of individuals killed by vehicles or dogs are otherwise healthy. This mortality has the potential to remove healthy

Threat	Status and severity [a]	Evidence
		breeding individuals from the population (Gonzalez-Astudillo 2018). Encounter mortality poses a significant threat during post-weaning dispersal, which occurs at a young age in both male and female koalas. Mature males are increasingly at risk as they have larger home ranges and increased mobility during the breeding season. Young males typically disperse more frequently and over larger distances than their female counterparts and the removal of subadult males by trauma has the potential to critically disrupt geneflow.
Disease and health		
Koala retrovirus (KoRV) and Chlamydia (*Chlamydia percorum*)	• Status: historical/current/future • Confidence: known • Consequence: severe • Trend: increasing • Extent: unknown	Wild populations carry disease pathogens. Inadvertent spread of disease also occurred historically following koala translocations. Disease can be a major contributor to population decline and reduces population viability. Chlamydia causes infertility, blindness and death (Polkinghorne et al. 2013). The prevalence of disease (chlamydiosis) has been found to increase following extreme stress from hot weather, drought, habitat loss and fragmentation (Lunney et al. 2012; Davies et al. 2013).

Status—identify the temporal nature of the threat;

Confidence—identify the extent to which we have confidence about the impact of the threat on the species;

Consequence—identify the severity of the threat;

Trend—identify the extent to which it will continue to operate on the species;

Extent—identify its spatial content in terms of the range of the species.

Each threat has been described in Table 1 in terms of the extent that it is operating on the species. The risk matrix (Table 2) provides a visual depiction of the level of risk being imposed by a threat and supports the prioritisation of subsequent management and conservation actions. In preparing a risk matrix, several factors have been taken into consideration, they are: the life stage they affect; the duration of the impact; and the efficacy of current management regimes, assuming that management will continue to be applied appropriately. The risk matrix and ranking of threats has been developed in consultation with the experts listed in DAWE (2021b) and in-house expertise using available literature.

Table 2 Risk matrix

Likelihood	Consequences				
	Not significant	**Minor**	**Moderate**	**Major**	**Catastrophic**
Almost certain	Low risk	Very high risk **Encounter mortality with**		Very high risk **Clearing of koala habitat**	Very high risk **Shrinking climate envelope**

Likelihood	Consequences				
	Not significant	Minor	Moderate	Major	Catastrophic
		vehicles and dogs		**koala retrovirus (KoRV) and Chlamydia** **Increased frequency of drought** **Increased frequency of heatwaves** **Increasing frequency of high-intensity bushfire**	**resulting in habitat loss**
Likely	Low risk	Moderate risk	High risk	Very high risk	Very high risk
Possible	Low risk	Moderate risk	High risk	Very high risk	Very high risk
Unlikely	Low risk	Low risk	Moderate risk	High risk	Very high risk
Unknown	Low risk	Low risk	Moderate risk	High risk	Very high risk

Threats in the above matrix have been classified according to likelihood of threat across the entire range of the listed koala population. It should be noted that at a smaller scale (e.g., regional scale) the risk of individual threats may be classified elsewhere in the table.

Categories for likelihood are defined as follows:

Almost certain – expected to occur every year

Likely – expected to occur at least once every five years

Possible – might occur at some time

Unlikely – such events are known to have occurred on a worldwide bases but only a few ties

Unknown – currently unknown how often the incident will occur

Categories for consequences are defined as follows:

Not significant – no long-term effect on individuals or populations

Minor – individuals are adversely affected but no effect at population level

Moderate – population recovery stalls or reduces

Major – population decreases

Catastrophic – population extirpation/extinction

Priority actions have then been developed to manage the threat particularly where the risk was deemed to be 'very high' or 'high'.

Conservation and recovery actions

The following conservation and recovery actions are identified and should be adhered to in conjunction with the latest guidance documents available on the Species Profile and Threats Database:

http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=85104.

Four supporting strategies and two on-ground (direct) strategies are included.

Supporting strategies:

Strategy 1: **Build and share knowledge**

Strategy 2: **Strong community engagement and partnerships**

Strategy 3: **Increase habitat protection**

Strategy 4: **Koala conservation is integrated into policy, and statutory and land-use plans**

On-ground strategies:

Strategy 5: **Strategic habitat restoration**

Strategy 6: **Active metapopulation management**

Supporting strategies provide for governance to coordinate actions, led by the Australian Government in partnership with the states and territory. They provide for research and capacity building to improve effectiveness of actions, from enhanced mapping, monitoring and survey methods; improved data collation, curation and analysis; to better sharing and communication of information; and building on community capacity, support and engagement. They also provide for improved planning frameworks and principles for state-level conservation planning for the listed koala.

Increasing the area of priority koala habitat that is protected is a key strategy to prevent further habitat loss and fragmentation and prevent further loss of koala populations. Once identified (Actions 1a-c), national areas of priority koala habitat should include areas of large intact landscapes that have the greatest potential to retain viable populations and have the potential to also act as source populations to adjacent areas.

On-ground (direct) strategies relate to improving habitat quality and restoration, and the suite of collective actions required to ensure metapopulation processes are maintained. The former will generally be implemented at the site-level, while the latter is a holistic landscape-scale approach to metapopulation management.

Many state-level actions have been ongoing, or recently commenced, under various state and territory environment-related, or koala-specific strategies (DES 2020; DPIE 2020).

Priorities assigned to actions under each of the six strategies are interpreted as follows:

Priority 1: Urgent. Prompt action is needed in advance of implementation of other management actions, to ensure effective coordination or to provide crucial

information for planning and management. Early action might also be necessary to avoid or mitigate the most significant threats.

Priority 2: Essential. Action is necessary to avoid or mitigate direct threats, implement planning and management, undertake research, and develop tools towards the long-term recovery.

Priority 3: Highly beneficial. Action is desirable, and while not critical, will provide for longer term maintenance of recovery.

Strategy 1: Build and share knowledge

The actions here comprise knowledge-based inputs or activities that support direct conservation actions. These inputs will provide information for a strategic and coordinated approach to koala conservation, now and into the near future using predictive climate change impacts. Without actioning these inputs, the ability to implement an effective listed koala recovery, will be significantly diminished.

Action No.	Description	Potential Partners/Responsibility	Timeframe (Priority)	Est. cost
1 a	Identify nationally important populations and habitat across the listed koala range under current conditions, and considering future impacts of climate change such as drought, heatwave, and fire, assessed by undertaking habitat distribution, population modelling and analysis (including abundance/density and genetic diversity), allowing for iterative updates using a robust scenario-based approach	Coordinated by the Commonwealth with state and territory government agencies using internal OR external mapping and modelling experts OR Expert Technical Advisory Panel of the National koala Recovery Team to be formed when the recovery plan is made OR researchers	Year 1 (1)	To be assessed (TBA)
1 b	Identify spatially and temporally strategic areas of high priority for: (i) restoration and revegetation based on koala and eucalypt population viability; (ii) climate and fire refugia; and (iii) corridors facilitating movement and metapopulation processes of koalas, allowing for iterative updates using a robust scenario-based approach.	Coordinated by the Commonwealth with state and territory government agencies, local government and natural resource management organisation Or NGOs Or researchers.	Year 1 and ongoing (1)	TBA
1 c	Develop prioritisation at regional or other appropriate scales for the long-term implementation of actions.	Coordinated by the Commonwealth with state and territory government agencies using internal OR external mapping and modelling experts OR Expert Technical Advisory Panel of the National koala Recovery Team to be formed when the recovery plan is made OR researchers	Year 2 (2)	TBA

Action No.	Description	Potential Partners/Responsibility	Timeframe (Priority)	Est. cost
1 d	In consultation with each range state and territory, including Victoria and South Australia, scope out and establish a fit-for-purpose long-term National koala Monitoring Program (NKMP) to improve understanding of trends in populations, distribution and population health across the koala's range, and efficacy of management interventions.	Coordinated by the Commonwealth with state and territory government agencies; community groups; non-government conservation organisations; koala research community; koala welfare organisations and the Expert Technical Advisory Panel of the National koala Recovery Team to be formed when the recovery plan is made	Year 1-2 (1)	$ 2 million
1 e	Implement National koala Monitoring Program; review design to ensure it remains fit-for-purpose and adaptive	Coordinated by the Commonwealth with state and territory government agencies; community groups; non-government conservation organisations; koala research community; koala welfare organisations and the Expert Technical Advisory Panel of the National koala Recovery Team to be formed when the recovery plan is made	Year 1 and ongoing (1)	TBA
1 f	Collate and synthesise existing data that may improve understanding of koala population dynamics and threat profiles across habitats and scales.	Coordinated by the Commonwealth with state and territory government agencies using internal OR external mapping and modelling experts OR Expert Technical Advisory Panel of the National koala Recovery Team to be formed when the recovery plan is made OR researchers	Years 1-5 (1)	TBA
1 g	Mapping of key metrics (distribution, habitat restoration, habitat condition and habitat loss) is reviewed at appropriate timeframes to detect changes, is coordinated across jurisdictions, and provides for landscape management now and at least three koala generations into the future.	Coordinated by the Commonwealth with state and territory government agencies using internal OR external mapping and modelling experts OR Expert Technical Advisory Panel of the National koala Recovery Team to be formed when the recovery plan is made OR researchers	Ongoing (1)	TBA
1 h	Coordinate pre-existing national and koala databases; coordinate and develop data standards (including metadata standards); survey and sampling design standards to improve the quality of koala monitoring (e.g., Community of Practice).	Coordinated by the Commonwealth with state and territory government agencies; koala research community; koala welfare organisations and the Expert Technical Advisory Panel of the National koala Recovery Team to be formed when the recovery plan is made	Years 1-5 (2)	TBA

Action No.	Description	Potential Partners/Responsibility	Timeframe (Priority)	Est. cost
1 i	Establish national research priorities targeted at applied outcomes, that inform and improve koala management. This action builds on priority research identified by Expert Technical Advisory Panel and the outputs of the first koala expert elicitation workshop for NSW (Hemming et al. 2018).	Coordinated by the Commonwealth with state and territory government agencies; koala research community; koala welfare organisations and the Expert Technical Advisory Panel of the National koala Recovery Team to be formed when the recovery plan is made	Ongoing (2)	TBA
1 j	Establish a recurring research forum to enhance existing collaboration among researchers, and between researchers, managers and other interested parties, to make the most effective use of research actions and to identify and address any further key knowledge gaps.	Coordinated by the Commonwealth with state and territory government agencies and Expert Technical Advisory Panel	Annually (2)	TBA
1 k	Facilitate a network to establish and support an active National koala Recovery Team and Expert Technical Advisory Panel, with strong governance in place.	Coordinated by the Commonwealth with state and territory government agencies	Year 1 (1)	TBA
1 l	Share knowledge across experts, government organisations, conservation groups, rescue and welfare groups, Indigenous groups and the general public through regular koala workshops and conferences. This includes a koala conference every five years that brings together researchers, policy makers, planners and interested conservation groups and citizens; and exceptional circumstance workshops, such as following responses after major crises (e.g., fire and drought).	Coordinated by the Commonwealth with state and territory government agencies and Expert Technical Advisory Panel of the National koala Recovery Team to be formed when the recovery plan is made	5 yearly (3)	TBA
1 m	Facilitate the ongoing capture, storage and subsequent sharing, including intergenerational transfer, of Traditional Knowledge on the koala within the Indigenous community and across civil society. Build and demonstrate the strong connection to koalas and their habitat maintained by Indigenous Australians (e.g., https://koala.nsw.gov.au/culture/)	Coordinated by Indigenous Australians in partnership with Commonwealth, State and Territory government agencies, NGOs and philanthropists	Ongoing (1)	TBA

Strategy 2: Strong community engagement and partnerships.

Successful koala conservation relies on a collaborative approach across all sectors, and communities have a key role to play in protecting local koalas. The high level of community support for the conservation of koalas provides an opportunity for a range of actions that contribute to shared goals, from formal partnerships for habitat protection to raising awareness. Actions include engaging citizens in koala conservation science, supporting and training professionals and koala carers in the community.

Action No.	Description	Potential Partners/Responsibility	Timeframe (Priority)	Est. cost
2 a	Grow partnerships with Indigenous and community groups and local government organisations to co-design opportunities for citizens to be involved in long-term koala monitoring programs and research.	Commonwealth, state and territory government resource in coordination with natural resource management organisations; National koala Recovery Team; Indigenous organisations; NGOs and the Zoo and Aquarium Association.	Ongoing (1)	TBA
2 b	Grow partnerships with Indigenous and community groups, non-government organisations and all level of governments to restore priority areas using best-knowledge revegetation guidelines for koala.	Commonwealth, state and territory government agencies in coordination with natural resource management organisations; National koala Recovery Team; Indigenous organisations and NGOs	Ongoing (1)	TBA
2 c	Develop active communication, education and extension strategies for businesses (developers, industries and rural land-owners' enterprises) aimed at koala habitat protection, incentives, partnership and compliance.	Commonwealth, state and territory government agencies in coordination with local government, natural resource management organisations	Ongoing (2)	TBA

Action No.	Description	Potential Partners/Responsibility	Timeframe (Priority)	Est. cost
2 d	Recognise the cultural and spiritual importance of the koala to Indigenous communities and engage to utilise, improve or reinvigorate their support and knowledge in koala conservation, citizen science and field activities. Strengthen cross-cultural and inter-generational knowledge exchange and develop partnerships for the management and conservation of koalas.	Commonwealth, state and territory government agencies in coordination with Indigenous land-owners, joint management partners and Indigenous ranger teams supported by natural resource management organisations, the National koala Recovery Team, and NGOs and the Zoo and Aquarium Association.	Ongoing (1)	TBA
2 e	Implement a comprehensive communication strategy for the plan's realisation.	Commonwealth, state and territory natural agencies and National koala Recovery Team; behavioural scientists	Ongoing (1)	TBA
2 f	Collaborate with existing database infrastructure to develop a user-friendly single-site portal for the general public to report koala sightings, together with awareness raising and encouragement; embed processes for regular updates and regular communication of information generated from the data.	Coordinated by the Commonwealth with state and territory government agencies; local NRM organisations and local government; NGOs and the Zoo and Aquarium Association.	Years 2-5 (1)	TBA

Action No.	Description	Potential Partners/Responsibility	Timeframe (Priority)	Est. cost
2 g	Build on existing guidance information with experts to develop national guidelines for veterinary standards in care, injuries, fertility control, disease treatment, tissue sampling, orphans and release for veterinarians, carers and koala rehabilitation centres; update and review to incorporate new learnings and knowledge.	Coordinated by the Commonwealth with state and territory government agencies, with input from research & veterinary experts; Expert Technical Advisory Panel; National Recovery Team; RSPCA and koala welfare organisations, including the Zoo and Aquarium Association.	Years 2-5 (2)	TBA
2 h	Implement community education and engagement programs in urban and peri-urban areas where impacts on koalas are high, incorporating best-practise understanding of values and attitudes towards koalas, responsible dog ownership and vehicle collisions and other urban issues resulting in koala deaths. These include, and are not limited to, developing and trialling innovative programs in koala aversion by dogs with owners; population and disease awareness; and reporting koala sightings.	State and territory government agencies in coordination with local government, traffic authorities and natural management organisations, welfare organisations, including the Zoo and Aquarium Association, and behavioural scientists; dog training organisations; RSPCA	Ongoing (1)	TBA

Strategy 3: Increase habitat protection

Land-use change is the most significant threat to the koala through habitat loss, fragmentation and degradation. Increasing the total area of protected, connected quality koala habitat in priority areas will be important to protect and recover koala populations. As koalas occur across different land tenures, notably private land, this will require a range of incentive mechanisms, including direct land purchases. Improvements in land management practices can also increase habitat protection without changing land use. While direct habitat protection forms some actions, this strategy primarily consists of developing incentives for such protection and thus this strategy has been included as a supporting strategy.

Action No.	Description	Potential Partners/Responsibility	Timeframe (Priority)	Est. cost
3 a	Increase the overall area of protected koala habitat by dedication of Crown land and purchasing land identified as priority koala habitat for incorporation into the state protected areas. Priority areas include those that support viable populations and those that have the greatest potential for population-level recovery.	States; territories; philanthropic investment	Ongoing (1)	TBA
3 b	Establish or expand existing targeted private land incentive mechanisms to increase the area for long-term protection and conservation of areas identified as priority koala habitats. Participation includes, but is not limited to, graziers, agricultural landholders, rural landholders, Indigenous land owners and private forestry.	States; territories; Commonwealth; philanthropic investment and NGOs. Indigenous land-owners and managers	Ongoing (2)	TBA
3 c	Improve the condition of existing koala habitat on both private and public land through altered land management practices, including management of vegetation, fire, weed, and introduced species.	State and territory government agencies; non-government land-owners; NGOs	Ongoing (2)	TBA
3 d	Investigate the potential to increase the protection of priority koala habitat through identification and registration of Critical Habitat where appropriate (i.e., Commonwealth-owned lands).	Commonwealth Government agencies; with strategic input from state and territory government agencies	Years 2-5 (2)	TBA

Strategy 4: koala conservation is integrated into policy, and statutory and land-use plans.

Management actions alone will not be sufficient to recover the koala. Actions are needed to ensure harmonisation of existing and future planning and policy settings such that they collectively contribute appropriately to maximising the chances of long-term survival of koalas in the wild.

Action No.	Description	Potential Partners/Responsibility	Timeframe (Priority)	Est. cost
4 a	Review and update EPBC Act referral guidelines for the listed koala to support regulatory decision making.	Commonwealth in consultation with state and territory governments, experts, planners, industry and the wider community,	Yr 1 (1)	$50,000
4 b	Review, revise, and strengthen where appropriate, statutory planning instruments, policies, and compliance controls at all levels of government, including local government, to avoid or minimise impacts of land use or land management on koala conservation. Embed principals of landscape-scale management.	State and territory government agencies in coordination with local government authorities; Commonwealth.	Yr 1 and ongoing (1)	TBA
4 c	Ensure identification and implementation of any offset decisions are strategic, coordinated, tracked in governments' databases, and informed by relevant planning and mapping documents such as NRM regional plans, Indigenous Heathy Country Plans associated with Indigenous Protected Areas (IPAs) or local government koala strategies.	Commonwealth, state and territory government agencies in coordination with local governments; National Recovery Team, Indigenous IPA managers	Yr 1 and ongoing (1)	TBA
4 d	Incorporate the impacts of climate change such as drought, heatwave and fire, into all strategic koala planning and actions, including restoration guidelines, offsets, translocation guidelines, forestry practices, corridor, reserve and protected area planning, allowing for iterative updates using a robust scenario-based approach	Commonwealth, state and territory government agencies in coordination with local governments	5 yearly (2)	TBA
4 e	Build on existing information to develop national guidelines or standards for koala-friendly urban design.	Commonwealth to coordinate state and territory government agencies, in consultation with local governments; urban planners	Yr 1 and ongoing (1)	TBA

Strategy 5: Strategic habitat restoration

Restoration increases the overall habitat available for koalas and increases the connectivity between areas of habitat, which is important to the long-term survival of koala populations. Many landcare-type organisations are restoring lost and degraded habitat for many species or to improve environmental functions. These activities are to ensure that resources are targeted to the most strategic areas.

Action No.	Description	Potential Partners/Responsibility	Timeframe (Priority)	Est. cost
5 a	Build on and implement landscape-scaled habitat restoration plans, including NRM regional plans, based on up-to-date mapping and spatial analysis that considers potential carrying capacity and landscape-scale	Coordinated approach between states and territory government agencies; local government; natural resource management agencies; NGOs	Ongoing (1)	TBA

	processes such as climate change, fire and drought, and koala movement patterns.			
5 b	Develop and implement best practice revegetation and restoration guidelines appropriate to local conditions that include planning for drought, heatwave, fire, and eucalypt responses to climate change using a robust scenario-based approach, consistent with national standards for ecological restoration (SERA 2017)	Coordinated between state and territory government agencies with input from research experts; Expert Technical Advisory Panel; natural resource management agencies and local community groups; NGOs	Years 1-5 (2)	TBA
5 c	Implement on-ground revegetation or restoration programs, following local restoration guidelines for the koala where they exist (e.g., NSW koala habitat revegetation guidelines (Wegner and Taws 2019)), in consultation with experts in koala ecology and plant geneticists. These should include experimental trialling of the establishment of climate resilient and nutritious feeding trees outside traditional ranges of koala habitat trees.	Coordinated approach between states and territory government agencies; local government; natural resource management agencies; local community groups; and NGOs.	Years 1-5 (2)	TBA

Strategy 6: Active metapopulation management

Metapopulation management concerns the movement of individuals and genes between populations. It is a complex and multi-faceted discipline. Adaptive management is the core of metapopulation management excellence. It requires consideration of cross-tenure land management, fire planning and operations, understanding of koala movement patterns and behavioural ecology, genetics, infection and disease, and fine-scale and macro-scale habitat needs, among other factors. To complicate these actions, planning instruments (e.g., development zoning) and forest harvesting practices are spatially variable, making it difficult to be prescriptive.

This strategy relies heavily on relevant and up-to-date habitat and distribution mapping and modelling for spatial prioritisation, climate change modelling, principles of landscape processes, and research into koala disease, population genetics habitat requirements, movement patterns, and biology. Management of fire, forest harvesting, and human activities and developments all influence koala metapopulations processes and must be managed to mitigate adverse impacts.

Action No.	Description	Potential Partners/Responsibility	Timeframe (Priority)	Est. cost
6 a	Develop meaningful and measurable metrics of health, genetics, population and distribution, at relevant planning scales, with triggers for management response. Integrate these triggers into metapopulation management, decision-making and programs. Implement response plans.	Commonwealth, state and territory government agencies, with input from research experts; National koala Monitoring Program; Expert Technical Advisory Panel and National Recovery Team	Years 1-5 (1)	TBA

Action No.	Description	Potential Partners/Responsibility	Timeframe (Priority)	Est. cost
6 b	Develop or build on existing best-practice koala translocation and post-care release guidelines for wild and captive populations, ensuring they are fit-for-purpose, informed by the latest research in metapopulation processes, genetics, disease and gut flora. Ensure the translocation guidelines are reviewed and updated within the life of this plan to integrate new understandings. If translocations are required, implement koala translocations in accordance with an appropriate decision framework and national guidelines (Wildlife Health Australia 2020), legislative requirements and consistent with international standards (IUCN/SSC 2013).	Coordinated by the Commonwealth with state and territory government agencies, with input from research experts; Expert Technical Advisory Panel & National Recovery Team; koala welfare organisations, including the Zoo and Aquarium Association, and RSPCA	5 yearly (2)	TBA
6 c	Regionally assess the feasibility, risks and cost-effectiveness of fire management options that seek to deliver long-term, strategic and landscape scale enhancement of the extent, and quality of current and future suitable habitat across tenures.	State and territory agencies with input from fire research experts; Expert Technical Advisory Panel and National Recovery Team; local fire authorities and local government, local landowners, Indigenous fire management practitioners & land-owners	Years 1-5 (1)	TBA
6 d	Develop and implement fire management that effectively secures and promotes long-term, strategic and effective protection of known populations and suitable habitat.	State and territory agencies with input from fire research experts; Expert Technical Advisory Panel and National Recovery Team; local fire authorities and local government; koala welfare organisations and RSPCA	Years 1-5 (1)	TBA
6 e	Develop and implement response and decision-support tools for individual and population management in emergencies such as bushfire, drought and floods. These include support and coordination of carer networks.	Coordinated by the Commonwealth with state and territory government resource agencies, local government agencies, natural resource management agencies and koala welfare organisations, with input from research experts; Expert Technical Advisory Panel and National Recovery Team	Years 1-5 (1)	TBA

Recovery plan decision

A decision has been made to have a Recovery Plan due to the 2012 recommendation by the Threatened Species Scientific Committee (TSSC 2012). This recovery plan is currently being drafted in parallel with this document.

Links to relevant implementation documents

Species Profile and Threats Database: http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=85104

Revised provisional list of animals requiring urgent management intervention following the 2019-2020 bushfires: https://www.environment.gov.au/biodiversity/bushfire-recovery/priority-animals

NSW koala Strategy: https://www.environment.nsw.gov.au/topics/animals-and-plants/threatened-species/programs-legislation-and-framework/nsw-koala-strategy

Saving our species Framework for the spatial prioritisation of koala conservation actions in NSW Iconic koala Project. https://www.environment.nsw.gov.au/research-and-publications/publications-search/framework-for-the-spatial-prioritisation-of-koala-conservation-actions-in-nsw

South East Queensland Koala Conservation Strategy: https://environment.des.Qld.gov.au/wildlife/animals/living-with/koalas/conservation/seq-koala-strategy

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): http://www.environment.gov.au/biodiversity/threatened/species/pubs/197-listing-advice.pdf

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The Threatened Species Scientific Committee finalised this assessment on 07 September 2021.

Attachment A: Listing Assessment for *Phascolarctos cinereus* combined populations of Queensland, New South Wales and the Australian Capital Territory

Reason for assessment

This assessment follows prioritisation of a nomination from the TSSC, initiated in response to the 2019/20 fires.

Assessment of eligibility for listing

This assessment uses the criteria set out in the EPBC Regulations. The thresholds used correspond with those in the IUCN Red List criteria except where noted in criterion 4, sub-criterion D2. The IUCN criteria are used by Australian jurisdictions to achieve consistent listing assessments through the Common Assessment Method (CAM).

Key assessment parameters

Table 3 includes the key assessment parameters used in the assessment of eligibility for listing against the criteria.

Table 3 Key assessment parameters

Metric	Estimate used in the assessment	Minimum plausible value	Maximum plausible value	Justification
Number of mature individuals	92,184	86,863	92,184	**Past population data for the listed koala:** **2001** population estimate used in calculations: 184,7400 Data hindcast from the 2012 expert elicitation (Adams-Hosking et al. 2016). **2012** population estimate: 115,600 Data source: 2012 expert elicitation (Adams-Hosking et al. 2016). **2021** population estimate: 92,200. **2032** population estimate: 63,500. Data sources: 2012 expert elicitation (Adams-Hosking et al. 2016) and 2021 expert elicitation (Legge et al. 2021)
Trend	contracting			
Generation time (years)	6.5 years	6 years	7 years	Using conservative values of sexual maturity at 3 years and longevity 15 years, generation time is estimated to be approximately 6.5 years. Here the three generation period is considered to be 20 years.

Extent of occurrence	1,665,850 km^2			Data provided by Department of Agriculture Water and Environment, Geoscience Australia and PSMA Australia.
Trend	contracting			
Area of Occupancy	19,428 km^2			The area of occupancy is estimated at 19,400 km^2. These figures are based on the mapping of point records from 2000 from state governments, museums and CSIRO. Due to the lack of recent surveys more recent data cannot be used to predict range contraction.
Trend	contracting Contracting due to climate related threats and habitat loss and land clearance.			
Number of subpopulations	>10			Geographically isolated populations exist throughout the koala's range due to habitat fragmentation resulting from large scale land clearing, drought and bushfire impacts. Populations West of the Great Dividing Range are considered to be isolated from their eastern counterparts (DAWE 2021b). Koala habitat is patchy and fragmented and increasingly prone to threats from drought resulting in multiple subpopulations (n≥3). In, Queensland, koala populations to the north (e.g., Wet Tropics), western inland arid regions (e.g., Mulga Lands) and southern end of the state (e.g., South East Queensland) are increasingly isolated due to habitat loss and fragmentation (DES 2020) (n≥3). In New South Wales, the east coast was heavily impacted by 2019-2020 bushfires. While the extent of bushfires was large, the fire intensity varied from low to high. Ongoing research indicates that areas of high intensity fire have zero koala occupancy in 2021. In contrast, low severity and moderate severity fire impacted areas are reported to have 100% koala occupancy (Pers comm., Natural Resources Commission 2021 koala Annual Forum). The high intensity fire impacts are likely to have the worst impact in poorly connected subpopulations (n≥5). Preliminary genetic analysis also confirms that there is no longer genetic exchange across the Clarence River in NSW, or from the north to

				the south of the Sydney basin (Eldridge & Lott 2020).
Trend	Declining The number of subpopulations is declining as climate suitable koala habitat shrinks.			
Basis of assessment of subpopulation number	The number of koala subpopulations is based on the available data and barriers to connectivity.			
No. locations	>10			
Trend	unknown			
Basis of assessment of location number	The spatial nature of the threats, although stochastic in time and space, is such that there are > 10 geographically or ecologically distinct areas where a single threatening event (e.g., drought or fire) could affect all of the individuals present within a single generation. The geographic location of non-impacted locations will vary between events, but there are always likely to be > 10.			
Fragmentation	Increasingly fragmented–e.g., by the 2019/20 fires.			
Fluctuations	Data deficient.			

Criterion 1 Population size reduction

Reduction in total numbers (measured over the longer of 10 years or 3 generations) based on any of A1 to A4			
	Critically Endangered Very severe reduction	**Endangered Severe reduction**	**Vulnerable Substantial reduction**
A1	≥ 90%	≥ 70%	≥ 50%
A2, A3, A4	≥ 80%	≥ 50%	≥ 30%

A1 Population reduction observed, estimated, inferred or suspected in the past and the causes of the reduction are clearly reversible AND understood AND ceased.

A2 Population reduction observed, estimated, inferred or suspected in the past where the causes of the reduction may not have ceased OR may not be understood OR may not be reversible.

A3 Population reduction, projected or suspected to be met in the future (up to a maximum of 100 years) [*(a) cannot be used for A3*]

A4 An observed, estimated, inferred, projected or suspected population reduction where the time period must include both the past and the future (up to a max. of 100 years in future), and where the causes of reduction may not have ceased OR may not be understood OR may not be reversible.

Based on any of the following

(a) direct observation [except A3]
(b) an index of abundance appropriate to the taxon
(c) a decline in area of occupancy, extent of occurrence and/or quality of habitat
(d) actual or potential levels of exploitation
(e) the effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites

Criterion 1 evidence

Eligible under Criterion 1 A2c, A4c **for listing as** Endangered

For the listed koala (Queensland, New South Wales and the Australian Capital Territory):

Generation length

Female koalas reach sexual maturity between 2 and 3 years of age (McLean & Handasyde 2007). In the wild, longevity can be more than fifteen years for females and more than twelve years for males (Martin & Handasyde 1999). IUCN Guidelines (2019) provide the following as one method for estimation of generation length:

> Age of first reproduction + [z * (length of the reproductive period)], where z is a number between 0 and 1

For mammals, values of z have been estimated at 0.29 and 0.284 (Pacifici et al. 2013; Keith et al. 2015).

Using conservative values of sexual maturity at 3 years and longevity 15 years, generation time is estimated to be approximately 6.5 years. Here the three generation period is considered to be 20 years.

Evidence - estimated

A2 Past population reductions (2001-2021):

The total number of koalas in Queensland, New South Wales, and the Australian Capital Territory in the year 2001 – the starting point for this assessment – was estimated to be between 184,748 and 170,335. This estimate was derived from bioregional population estimates for 2012 provided by Adams-Hosking et al. (2016). These bioregional estimates sum to a total population of 115,614 in 2012 (Adams-Hosking et al. 2016); a figure that is widely accepted by state governments, non-government organisations (NGOs) and researchers and builds on the 2012 EPBC listing advice (TSSC 2012). The 2012 bioregional population estimates were adjusted by Adams-Hosking et al.'s (2016) estimates of the rate of decline in each bioregion over the preceding three generations to yield bioregional population estimates for the year 1992. We then derived bioregional values for the year 2001 by assuming that the form of decline in each bioregion between 1992 and 2012 was either linear (giving the summed estimate of 184,748) or exponential (170,335); note that Adams-Hosking et al. (2016) did not specify the shape of the decline curve over the three-generation period. Total population estimates for the year 2021 were derived similarly, by projecting the bioregional declines from 1992-2012 forward to 2021. The resulting values for the total population in 2021 were 92,184 (linear decline) and 86,863 (exponential decline) (Table 4, Box 1).

Table 4 shows that that for the period 2001 to 2021 the estimated decline of the total population reaches the Endangered threshold of 50 percent under this Criterion. Whether the shape of the decline curve is exponential or linear has little effect on the outcome. Key bioregions (e.g., Mulga Lands) likely did not decline in a linear or exponential fashion, but rather were relatively stable until around 2000 then declined precipitously due to the Millennium Drought (Seabrook et al. 2011). If this "step change" were factored into the calculations in Table 4 it would have the effect of estimating a higher population at the beginning of the assessment period for Criterion A2, and thus a proportionally higher rate of decline.

Additionally, these data do not include the effects of the 2019/20 bushfires. While fire was considered as a threat in the elicitation exercise of Adams-Hosking et al. (2016), fires of the scale of 2019/20 were not anticipated in estimating declines that were likely to occur after 2012 (Hosking, Kavanagh, Lawler, Lunney, Melzer, Menkhorst, Moore pers comm April 2021). Thus again, this analysis likely underestimates the overall decline.

In a project run by the Threatened Species Recovery Hub in 2020-21, expert elicitation was used to estimate the likely mortality of koalas in low/med and high/very high severity fires. These estimates were then combined with spatial estimates of the proportion of the listed koala's range that was burned in those severity classes, to estimate the overall population reduction caused by the fire. It was estimated that populations declined by 10 percent (80 percent confidence 5.0 to 17 percent) by one year after 2019/20 fires, and that they would continue to decline thereafter without returning to their pre-fire population size. This analysis assumed uniform density of koalas across their range. However, the fires occurred predominantly in areas where koala densities are relatively higher than, for example, in large parts of their range west of the Great Divide, and thus this estimate likely underestimates the mortality due to the fires.

The estimated decline sits on the lower threshold for the Endangered category. Thus, while the effects of the "step change" due to drought and the similar sudden drop in numbers due to the 2019/2020 fires cannot be accurately quantified, it can confidently be concluded that they move

the estimate well into the Endangered range. They are unlikely to be of sufficient scale to reach the threshold for the Critically Endangered category, which would require an overall decline of ≥80 percent for this criterion (Table 4). Consequently, given that the koala is demonstrably close to the lower threshold of Endangered and that ongoing trends suggest further events likely to be sufficient to worsen the decline, the Committee considers that the koala is eligible for listing as Endangered under this subcriterion A2c.

Table 4 – Estimated population sizes for bioregions containing koalas, calculated from the values provided in an expert elicitation study estimating koala sizes and trends +/- three generations from 2012.

Values for 2032 generated directly by applying three generation trends. Values for 2001 estimated by hindcasting three generations back to 1992 then calculated based on assuming either constant linear, or exponential, decline across the three generation period. Values for 2021 also based on constant linear, or exponential, decline between 2012 and 2032. Full details of these calculations are shown in Box 1 for the Brigalow Belt North bioregion as an exemplar.

Bioregion	2012	Past or future change (%) over 3 gens	Hindcast (ca 1992)	2001 linear	2021 linear	2001 exponential	2021 exponential decline	Forecast (ca. 2032)
				A2				A4
Cobar Peneplain & Riverina	2,354	-9	2,587	2,482	2,259	2,480	2,256	2,142
Darling Riverine Plains	964	-34	1,461	1,237	816	1,212	800	636
Mulga Lands (NSW)	711	-31	1,030	886	612	872	602	491
Murray Darling Depression	55	-12	63	59	52	59	52	48
New England Tablelands	2,771	6	2,614	2,685	2,846	2,683	2,845	2,937
NSW North Coast	8,367	-50	16,734	12,969	6,485	12,250	6,125	4,184
NSW South Western Slopes	2,310	-23	3,000	2,690	2,071	2,667	2,054	1,779
South Brigalow & Nandewar	11,133	-35	17,128	14,430	9,379	14,110	9,171	7,236
South East Corner	655	-46	1,213	962	520	919	496	354
South Eastern Highlands	1,363	-19	1,683	1,539	1,246	1,531	1,240	1,104
Sydney Basin	5,667	-4	5,903	5,797	5,565	5,796	5,564	5,440
Brigalow Belt North	15,179	-63	41,024	29,394	10,876	26,226	9,704	5,616
Brigalow Belt South	11,071	-56	25,161	18,821	8,281	17,389	7,651	4,871
Central Mackay Coast	8,857	-35	13,626	11,480	7,462	11,225	7,296	5,757
Desert Uplands	6,357	-20	7,946	7,231	5,785	7,187	5,750	5,086
Einasleigh Uplands & Wet Tropics	4,750	-41	8,051	6,566	3,874	6,349	3,746	2,803
Mitchell Grass Downs	1,943	-39	3,185	2,626	1,602	2,550	1,556	1,185
Mulga Lands (QLD)	15,286	-73	56,615	38,017	10,264	31,408	8,480	4,127
South Eastern Queensland	15,821	-51	32,288	24,878	12,190	23,422	11,477	7,752
TOTAL	**115,614**		**241,312**	**184,748**	**92,184**	**170,335**	**86,863**	**63,549**
Estimated decline over three generations				**50%**		**49%**		**45%**

Box 1. Example of calculations used in calculating time-corrected estimates - Brigalow Belt North Bioregion

Notes:
1. Because the estimated declines rates vary between bioregions, the calculations were made for each bioregion and summed across the relevant area to provide overall estimates. One bioregion is shown here as an exemplar.
2. For simplicity, numbers used below are rounded, but this was not the case when calculations were made on a spreadsheet and thus it may appear that there are minor discrepancies with Table 4.

Adams-Hosking et al. (2016) estimated that in 2012 the population of koalas in this bioregion was 15,179 and that the decline over the past, and future, three generations from 2012 was 63 percent.

Hindcast to previous three generations from 2012 (i.e., approximately 1992)
$N_{2012} = N_{1992}*(100\%-63\%)$
$N_{2012} = N_{1992}*37\%$
$N_{2012}/37\% = N_{1992}$
$N_{1992} = 15,179/37\%$
$= 41,024$

Forecast to following three generations from 2012 (i.e., approximately 2032)
$N_{2032} = N_{2012}*(100\%-63\%)$
$= 15,179*.37$
$= 5,616$

Estimating population at beginning of relevant three generation time period for Criterion A2 (i.e., approx. 2001)
Assuming linear decline
$N_{2012} = 15,179$
$N_{1992} = 41,024$
$Decline/year = (N_{2012} - N_{1992})/(2012-1992)$
$= (41,024-15,179)/20$
$= 25,845/20$
$= 1292$
$N_{2001} = N_{1992}-(Decline/year)*(2001-1992)$
$= 41,024-(1292*9)$
$= 29,394$

Assuming exponential decline
$N_{1992} = 41,024$
Decline over 20 years = 63%
Remaining = 37% = 0.37
$Decline/year = 0.37^{(1/20)} = 0.952$
$N_{2001} = N_{1992}*0.952^{(2001-1992)}$
$= N_{1992}*0.952^{9}$
$= 41,024*0.639$
$= 26,226$

Estimating population at end of relevant three generation time period for Criterion A2 (i.e., approx. 2021)

Assuming linear decline

N_{2012} = 15,179
N_{2032} = 5,616
Decline/year = (N_{2032} - N_{2012})/(2032-2012)
= (15,179-5,616)/20
= 9,563/20
= 478
N_{2021} = N_{2012}-(Decline/year)*(2032-2012)
= 15,179-(478*9)
= 10,786

Assuming exponential decline
N_{2012} = 15,179
Decline over 20 years = 64%
Remaining = 37% = 0.37
Decline/year = $0.37^{(1/20)}$ = 0.952
N_{2021} = N_{2012}*$0.952^{(2021-2012)}$
= N_{2012}*0.952^{9}
= 15,179*0.639
= 9,704

A3 Population reductions (2021-2042):

The Committee has determined that there are insufficient data to appropriately address Criterion A3 for the koala. As above, the primary data source from which to address both population size and trend is the paper by Adams-Hosking et al. (2016). As that paper addresses the period only until three generations into the future from 2012, extending the period until 2042 would require inappropriately extrapolating by approximately a decade.

A4 Population reductions (2012-2032):

Table 4 shows a decline rate of 45 percent over the relevant three generation moving window from 2012 to 2032 (without including effects of the 2019/20 bushfires). That this is a lower overall rate than the period 2000-2021 may seem counterintuitive. This is explained by the fact that several of the highest rates of decline within bioregions occur in those bioregions with the largest population size. In earlier years, those populations constitute a higher proportion of the overall population than in subsequent years and lead to a higher overall rate of decline because they decline faster than the overall population. Consequently, as they diminish in size, they contribute less to the overall population decline and this rate itself decreases.

When the 2019/20 bushfires are factored into the declines for relevant bioregions the result approaches or exceeds the Endangered threshold, but it is difficult to quantify this because of the different data structures used in the relevant studies, particularly the absence of partitioning by bioregion by the Threatened Species Recovery Hub analysis (Legge et al. 2021) .

The Committee must also judge the likelihood of an additional event in the next decade sufficient to increase ongoing decline to ≥50 percent. In this context, it is notable that Australia has experienced two severe droughts in the last 20 years (Millennium Drought, Big Dry), several large scale fire events (e.g. 2009 Victorian fires, 2019/20 bushfires) and that climate models suggest both phenomena will become both more common and more severe (Di Virgilio et al. 2019; Abram et al. 2021). Consequently, given that the koala is demonstrably close to the lower

threshold of Endangered and that ongoing trends suggest further events likely to be sufficient to worsen the decline, the Committee considers that the koala is eligible for listing as Endangered under subcriterion 1A4c.

Criterion 2 Geographic distribution as indicators for either extent of occurrence AND/OR area of occupancy

		Critically Endangered Very restricted	Endangered Restricted	Vulnerable Limited
B1.	Extent of occurrence (EOO)	**< 100 km²**	**< 5,000 km²**	**< 20,000 km²**
B2.	Area of occupancy (AOO)	**< 10 km²**	**< 500 km²**	**< 2,000 km²**
AND at least 2 of the following 3 conditions:				
(a)	Severely fragmented OR Number of locations	**= 1**	**≤ 5**	**≤ 10**
(b)	Continuing decline observed, estimated, inferred or projected in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) area, extent and/or quality of habitat; (iv) number of locations or subpopulations; (v) number of mature individuals			
(c)	Extreme fluctuations in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) number of locations or subpopulations; (iv) number of mature individuals			

Criterion 2 evidence

Eligible under Criterion 2

Not eligible

The extent of occurrence (EOO) is estimated at 1,665,850 km² and the area of occupancy (AOO) is estimated at 19,428 km². These figures are based on the mapping of point records from a 20-year period (2000–2020), obtained from state governments, museums, and CSIRO. The EOO was calculated using a minimum convex hull, and the AOO calculated using a 2x2 km grid cell method, based on the IUCN Red List Guidelines 2014 (IUCN 2019). The AOO is likely significantly under-estimated due to limited sampling across the occupied range (Woinarski et al. 2014).

The data presented above demonstrate the subspecies is not eligible for listing under this criterion as the EOO is > 20,000 km² and the AOO is > 2,000 km².

Criterion 3 Population size and decline

		Critically Endangered Very low	Endangered Low	Vulnerable Limited
Estimated number of mature individuals		**< 250**	**< 2,500**	**< 10,000**
AND either (C1) or (C2) is true				
C1. An observed, estimated or projected continuing decline of at least (up to a max. of 100 years in future)		**Very high rate 25% in 3 years or 1 generation (whichever is longer)**	**High rate 20% in 5 years or 2 generation (whichever is longer)**	**Substantial rate 10% in 10 years or 3 generations (whichever is longer)**
C2. An observed, estimated, projected or inferred continuing decline AND its geographic distribution is precarious for its survival based on at least 1 of the following 3 conditions:				
(a)	(i) Number of mature individuals in each subpopulation	**≤ 50**	**≤ 250**	**≤ 1,000**
	(ii) % of mature individuals in one subpopulation =	**90 – 100%**	**95 – 100%**	**100%**
(b) Extreme fluctuations in the number of mature individuals				

Criterion 3 evidence

Eligible under Criterion 3

Not eligible

The estimated population size is > 10,000 mature individuals. The data presented above demonstrates that the koala is not eligible for listing under this criterion.

Criterion 4 Number of mature individuals

	Critically Endangered Extremely low	Endangered Very Low	Vulnerable Low
D. Number of mature individuals	< 50	< 250	< 1,000
D2.[1] *Only applies to the Vulnerable category* Restricted area of occupancy or number of locations with a plausible future threat that could drive the species to critically endangered or Extinct in a very short time			D2. Typically: area of occupancy < 20 km² or number of locations ≤ 5

[1] The IUCN Red List Criterion D allows for species to be listed as Vulnerable under Criterion D2. The corresponding Criterion 4 in the EPBC Regulations does not currently include the provision for listing a species under D2. As such, a species cannot currently be listed under the EPBC Act under Criterion D2 only. However, assessments may include information relevant to D2. This information will not be considered by the Committee in making its recommendation of the species' eligibility for listing under the EPBC Act, but may assist other jurisdictions to adopt the assessment outcome under the *common assessment method*.

Criterion 4 evidence

Eligible under Criterion 4

Not eligible

The data presented above demonstrates that the koala is not eligible for listing under this criterion. The number of individuals is > 1,000 and the AOO is > 20 km², and there are > 5 locations.

Criterion 5 Quantitative analysis

	Critically Endangered Immediate future	Endangered Near future	Vulnerable Medium-term future
Indicating the probability of extinction in the wild to be:	≥ 50% in 10 years or 3 generations, whichever is longer (100 years max.)	≥ 20% in 20 years or 5 generations, whichever is longer (100 years max.)	≥ 10% in 100 years

Criterion 5 evidence

Eligible under Criterion 5 for listing as Insufficient data

Insufficient data to determine eligibility

Population viability analysis has not been undertaken. Therefore, there is insufficient information to determine the eligibility of the species for listing in any category under this criterion.

Adequacy of survey

The survey and modelling effort has been considered adequate and there is sufficient scientific evidence to support the assessment.

Public consultation

Notice of the proposed amendment and a consultation document was made available for public comment for 30 business days between 18 May 2021 and 30 July 2021.

Listing and Recovery Plan Recommendations

The Threatened Species Scientific Committee recommends:

(i) that the list referred to in section 178 of the EPBC Act be amended by transferring *Phascolarctos cinereus* from the Vulnerable category to the Endangered category.

(ii) that there should be a recovery plan for this species.

Attachment B: Experts consulted with during the preparation of the Conservation Advice

Note: A National koala monitoring workshop was held February 1-2, 2021. Koala experts provided direct input to the Conservation Advice during this workshop. The workshop participants are included in the list of experts consulted with alongside other experts who provided additional advice.

Name	**Organisation/Affiliation**
Adam Leavesley	ACT Parks and Conservation
Adam Roff	NSW Department of Planning, Industry and Environment
Allen Mcllwee	NSW Department of Planning, Industry and Environment
Andrew Hoskins	CSIRO
Anthony Contarino	QLD Department of Environment and Science
Ben Moore	Western Sydney University
Bill Ellis	University of Queensland
Billie Roberts	NSW Department of Planning, Industry and Environment
Brad Law	NSW Department of Primary Industries
Bronte Kulp	QLD Department of Environment and Science
Carsten Kuelheim	Michigan Technological University, USA (formerly at: Australian National university)
Cassie Thompson	NSW Natural Resources Commission
Catherine George	QLD Department of Environment and Science
Chris Meakin	Commonwealth Department of Agriculture, Water and the Environment
Sue Fyfe	Commonwealth Department of Agriculture, Water and the Environment
Claire Runge	University of Queensland
Christine Hosking	The University of Queensland
Cristina Vicente	SA Department for Environment and Water

Damian Higgins	University of Sydney
Dan Lunney	NSW Department of Planning, Industry and Environment
Danielle Stocks	NSW Department of Planning, Industry and Environment
David Ramsey	Vic Department of Environment, Land, Water and Planning
David Westcott	CSIRO
Debbie Saunders	Wildlife Drones
Desley Whisson	Deakin University
Emma Hickingbotham	Vic Department of Environment, Land, Water and Planning
Enhua Lee	NSW Department of Planning, Industry and Environment
Grant Hamilton	Queensland University of Technology
Harriet Preece	QLD Department of Environment and Science
Helen Murphy	CSIRO
Helene Marsh	Threatened Species Scientific Committee
Ian Sandford	QLD Department of Environment and Science
Ivan Lawler	Commonwealth Department of Agriculture, Water and the Environment
Jane DeGabriel	NSW Department of Planning, Industry and Environment
Jacob Tangey	QLD Department of Environment and Science
Jennie Mallela	Commonwealth Department of Agriculture, Water and the Environment
Jim Adams	National Landcare Network
John Turbill	NSW Department of Planning, Industry and Environment
Jonathan Rhodes	University of Queensland
Julie Anorov	Commonwealth Department of Agriculture, Water and the Environment

Kaitlyn Close	QLD Department of Environment and Science
Kara Youngentob	Australian National University
Karen Ford	Australian National University
Karl Hillyard	SA Department for Environment and Water
Kath Handasyde	University of Melbourne
Katherine Belov	University of Sydney
Kellie Leigh	Science for Wildlife
Kyle Debets	QLD Department of Environment and Science
Kylie Madden	NSW Department of Planning, Industry and Environment
Lachlan Wilmott	NSW Department of Planning, Industry and Environment
Laine Edwards	Commonwealth Department of Agriculture, Water and the Environment
Laura Griffiths	Commonwealth Department of Agriculture, Water and the Environment
Lauren Smith	Commonwealth Department of Agriculture, Water and the Environment
Lily Sekuljica	NSW Department of Planning, Industry and Environment
Linda Neaves	Australian National University
Lynne McCarthy	Commonwealth Department of Agriculture, Water and the Environment
Manda Page	QLD Department of Environment and Science
Mark Eldridge	Australian Museum
Mathew Crowther	University of Sydney
Michelle Hutchins	Commonwealth Department of Agriculture, Water and the Environment
Mike Roache	NSW Department of Planning, Industry and Environment
Nerilie Abram	Australian National University

Nicholas Connor	NSW Department of Planning, Industry and Environment
Nicole Gallahar	NSW Department of Planning, Industry and Environment
Olivia Woosnam	OWAD Environment
Peter Latch	Commonwealth Department of Agriculture, Water and the Environment
Peter Menkhorst	Vic Department of Environment, Land, Water and Planning
Renae Hockey	NSW Department of Planning, Industry and Environment
Renee Brawata	ACT Government, Environment, Planning and Sustainable Development
Richard Davies	NSW Department of Planning, Industry and Environment
Rod Pietsch	NSW Department of Planning, Industry and Environment
Romane Cristescu	University of Southern Queensland
Rowan Ewing	National Landcare Australia
Ryan Witt	University of Newcastle
Sarah Bloustein	Commonwealth Department of Agriculture, Water and the Environment
Sarah Brown	Commonwealth Department of Agriculture, Water and the Environment
Sarah Legge	NESP Threatened Species Recovery Hub
Sarah Sargent	QLD Department of Environment and Science
Shane Norrish	National Landcare Australia
Steven Howell	QLD Department of Environment and Science
Tanya Pritchard	WWF
Vural Yazgin	Vic Department of Environment, Land, Water and Planning
Warrick McGrath	Vic Department of Environment, Land, Water and Planning
Zoe Kemp	QLD Department of Environment and Science

Attachment C: Additional Sources of Information Provided during the Public Consultation

Note: Additional sources of information provided during the public consultation process, that are not referred to in the Conservation Advice, are detailed here. Each has been considered with respect to finalising the Committee's recommendation and whether it materially affected the outcome or the recommended conservation actions. The inclusion of a source here does not necessarily indicate that the Committee agrees with its conclusion(s).

Biolink (2017). Koala Habitat & Population Assessment: Lismore Local Government Area (part). Final report to Lismore City Council. Biolink Ecological Consultants, Uki NSW.

Biolink (2019) The Kiwarrak and Khappinghat ARKS: Aspects of the distribution and abundance of koalas. Final report to mid Coast Council. Biolink Ecological Consultants, UKI NSW.

Biolink (2020) A review of the conservation status of the NSW populations of the koala (Phascolarctos cinereus) leading up to and including part of the 2019/20 fire event.

Biolink (2020) A review of the conservation status of the QLD population of the koala (Phascolarctos cinereus) leading up to and including the 2019 fire events. Available at: file:///C:/Users/A27456/Downloads/A%20Review%20of%20the%20Conservation%20Status%20of%20QLD%20Koalas.pdf

Biolink 2020 Burleigh Ridge koala survey data analysis & Population Viability Analysis. Final Report to City of Gold Coast May 2020. Revised August 2020

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Cataloguing data

This publication (and any material sourced from it) should be attributed as: Department of Agriculture, Water and the Environment 2022, Conservation advice for *Phascolarctos cinereus* (Koala*)*, Canberra.

This publication is available at the SPRAT profile for *Phascolarctos cinereus* (Koala).

Department of Agriculture, Water and the Environment
GPO Box 858, Canberra ACT 2601
Telephone 1800 900 090
Web awe.gov.au

Version history table

Document type	Title	Date
Conservation Advice	Department of Sustainability, Environment, Water, Population and Communities (2012). Approved Conservation Advice for Phascolarctos cinereus (combined populations in Queensland, New South Wales and the Australian Capital Territory). Canberra: Department of Sustainability, Environment, Water, Population and Communities.	02 05 2012
Listing Advice	Threatened Species Scientific Committee (TSSC) (2012). Listing advice for Phascolarctos cinereus (Koala)	02 05 2012