The Minister approved this conservation advice and retained this species in the Endangered category, effective from 01/02/2018

# Conservation Advice

# *Bettongia penicillata*

woylie

*Note: The information contained in this conservation advice was primarily sourced from 'The Action Plan for Australian Mammals 2012' (Woinarski et al., 2014). Any substantive additions obtained during the consultation on the draft has been cited within the advice. Readers may note that conservation advices resulting from the Action Plan for Australian Mammals show minor differences in formatting relative to other conservation* advices. *These reflect the desire to efficiently prepare a large number of advices by adopting the presentation approach of the Action Plan for Australian Mammals, and do not reflect any difference in the evidence used to develop the recommendation.*

## Taxonomy

Conventionally accepted as *Bettongia penicillata* (Gray 1837).

Two subspecies are recognised:
*B. p. penicillata* in south-eastern Australia, now Extinct; and
*B. p. ogilbyi* in south-western Australia.

The subspecific classification of *Bettongia penicillata* is unresolved. It is possible that the two subspecies represent distant ends of a cline that terminated in south-eastern Australia (subspecies *penicillata*) and south-western Australia (subspecies *ogilbyi*). A species in northern Queensland (*B. tropica*) was originally described as a subspecies *of B. penicillata*, but is no longer recognised as part of that species.

This assessment applies to the entire species, *B. penicillata*, although only one subspecies, *B. p. ogilbyi*, is extant.

## Summary of assessment

### Conservation status

Endangered: Criterion 1 (A2)(b)(e) and Criterion 2 B2(a),(b)(ii,iii,iv).

Following a formal review of the listing status of *Bettongia penicillata*, the Threatened Species Scientific Committee (the Committee) has determined that, although the species underwent a very severe reduction in numbers between 1998 and 2013, evidence of a population increase since 2014 does not support a change of status of the species under the EPBC Act. Therefore, the Committee concluded that *Bettongia penicillata* should remain listed as Endangered under the EPBC Act.

Species can be listed as threatened under state and territory legislation. For information on the listing status of this species under relevant state or territory legislation, see http://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl

### Reason for conservation assessment by the Threatened Species Scientific Committee

This advice follows assessment of new information provided to the Committee to change the listing status of *Bettongia penicillata.*

## Public consultation

Notice of the proposed amendment and a consultation document was made available for public comment for 32 business days between 30 January 2017 and 15 March 2017. Any comments received that were relevant to the survival of the species were considered by the Committee as part of the assessment process.

## Species/subspecies information

### Description

The woylie is a small marsupial with adult males weighing 1–1.8 kg and adult females weighing 0.75–1.5 kg. The head and body length is 300–360 mm for males and 280–350 mm for females; the tail length is 250–360 mm (de Tores & Start 2008). The fur is grey to greyish brown on the back and flanks, and pale greyish on the undersides. The tail is dark and has a distinctive black brush at the end (de Tores & Start 2008). Woylies carry nesting material in the curled tip of their tail which is prehensile (adapted for grasping) (Troughton 1973; Christensen 1980).

Other common names include the brush-tailed bettong and the brush-tailed rat-kangaroo. Woylie ('Woli' according to Noongar orthography) is a Noongar Aboriginal name for this species (Abbott 2001). Other Indigenous names include Woylyer and Karpitchi.

### Distribution

Natural populations

Formerly very widespread, woylies once occupied most of the Australian mainland south of the tropics. Their range included the arid and semi-arid zones of Western Australia, the Northern Territory, South Australia, New South Wales and Victoria, and possibly extended north along the east coast into Queensland. Indigenous oral history has confirmed that woylies were broadly distributed in the central deserts — ranging over much of the Gibson Desert in central Western Australia and into the southern region of the Northern Territory (Burbidge & Fuller 1984, Burbidge et al., 1988). Woylies also occurred on Saint Francis and St Peter Islands in South Australia (Robinson et al., 1996).

Based on modern, historical and subfossil records, woylies previously occurred in 28 of Australia's 85 bioregions, and are now extinct in all but two (Burbidge et al., 2009). Like many medium-sized terrestrial mammals in arid and semi-arid Australia, the species' range contracted to the most mesic (mild) parts of its former range after European settlement (Burbidge & McKenzie 1989). In arid Australia, woylies survived the establishment of feral cats (*Felix catus*), but disappeared soon after the establishment of foxes (*Vulpes vulpes*) (Burbidge et al., 1988). By 1970, woylies remained in only four subpopulations in south-west Western Australia: Dryandra Woodland, Tutanning Nature Reserve, and two within the Upper Warren region (Kingston and Perup). Molecular analysis of these four subpopulations revealed that the Tutanning subpopulation is genetically distinct and has lower genetic diversity than the other populations (Pacioni et al., 2011).

Following widescale fox baiting and reintroduction projects implemented under the Western Shield program in Western Australia, and similar programs in other states, the distribution and abundance of the woylie subsequently increased, leading to its removal from threatened species listings in 1998−1999 (Start et al., 1998; TSSC 2009). However, in the 2000s sudden and dramatic declines in the population occurred. The population declined by approximately 90 percent from 1999 to 2006 (Wayne et al., 2013). The species was re-listed as Endangered under the EPBC Act in 2009 (TSSC 2009). The cause of the declines was previously unclear, but a 2015 study in the wheatbelt region of Western Australia identified that an increase in the number of feral cats following sustained fox control was the most likely cause; predation by feral cats caused most of the mortalities (65 percent) and was three times the fox predation rate (21 percent) (Marlow et al., 2015).

Re-introductions

The species has been re-introduced with mixed success to numerous sites in Western Australia (WA), South Australia (SA) and New South Wales (NSW), including a number of wildlife sanctuaries and fenced mainland 'islands' (Priddell & Wheeler 2004; Wayne et al., 2011; Yeatman & Groom 2012). To be included in this assessment populations need to fulfil the criteria for inclusion, as per the IUCN Red List Guidelines 2017. A total of twenty-eight localities are included in this assessment (Table 2), but the populations at some of these have become functionally extinct over the past three generation (9−15 year) period relevant to this assessment.

**Relevant biology/ecology**

Woylies originally inhabited a wide range of landscapes. In the western deserts, Indigenous people reported that they occupied sand plains and dunes with *Triodia* spp. (spinifex) hummock grassland. The remnant subpopulations in south-western Australia inhabit woodlands and adjacent heaths with a dense understorey of shrubs, particularly *Gastrolobium* spp. (poison pea), which contain monofluoroacetic acid (from which the compound present as sodium monofluoroacetate in the vertebrate pesticide '1080' is derived). Their diet is primarily underground fungi, but also includes tubers, bulbs and seeds. Woylies can store seed in their cheek pouches for later caching and are a major distributor of fungal spores and seeds (Murphy et al., 2005). Their digging also has a positive impact on the non-wetting property of soils (Garkaklis et al., 1998).

Woylies rest during the day in a well-concealed nest built over a shallow depression. The nest is most commonly built using long strands of grasses, but other material such as strips of bark are also used (in the forest) or dried seagrass and/or spinifex (in arid coastal areas) (Christensen & Leftwich 1980; Armstrong pers. comm., 2006 cited in Freegard 2007). When disturbed from the nest, woylies will move quickly with head low and tail extended, sometimes colliding with obstacles in their haste to flee.

Woylies are solitary animals, but nest sharing, usually by the mother and young at heel, has been recorded (Sampson 1971; Christensen & Leftwich 1980; Start et al., 1995). The size of home ranges varies between habitats, sites and according to woylie density. Small home ranges (less than 6 ha) are generally observed at high population densities (Nelson et al., 1992; Hide 2006). Males tend to have larger home ranges than females (Sampson 1971; Leftwich 1983), although this is not always so when woylies are at higher densities (Yeatman 2010). Experimental and field observations show that individuals are capable of moving 3−9 km (Pacioni et al., 2011).

Woylies can breed continuously throughout the year (Sampson 1971). It is not uncommon for a large proportion of females at a monitoring site to be either carrying young or suckling a young at heel. The proportion of females caring for young tends to be lower in the drier months when conditions for survival are harsher. Woylies produce a single young at a time, but twins have occasionally been observed (Sampson 1971; A. Wayne pers. comm., cited in Woinarski et al., 2014). Woylies exhibit embryonic diapause, so it is possible for females to carry a blastocyst in the uterus, young in the pouch and have a young at heel (Smith 1989, 1996). They have the potential to breed continuously, producing a maximum of three young in a year (Serventy 1970). Pouch life is 90-100 days (de Tores & Start 2008; Yeatman & Groom 2012).

Females can breed at around 6 months of age (de Tores & Start 2008). Maximum life spans in the wild in Upper Warren are seven years for females and nine years for males (A. Wayne pers. comm., cited in Woinarski et al., 2014). Minimum life spans at Scotia are 4.5 years (S. Legge pers. comm., cited in Woinarski et al., 2014). Life spans of up to 14 years and 18 years have been recorded in captivity (Keynes 1989; AnAge 2012). Population viability analysis modelling has shown that, under severe predation, generation time in the wild for females is 2.43 years and for males 2.65 years (Pacioni 2010). Generation length for wild populations under moderate predator pressure is assumed to be 3-5 years (Woinarski et al., 2014).

**Threats**

The main threats to the woylie are predation by foxes and feral cats (Table 1).

Table 1 – Threats to the woylie in approximate order of severity of risk, based on available evidence

| Threat factor | Consequence rating | Extent over which threat may operate | Evidence base |
|---|---|---|---|
| Predation by foxes (*Vulpes vulpes*) | Severe to catastrophic | Large (entire mainland range) | Foxes are a significant predator of woylies and have caused declines and local extinctions (Kinnear et al., 2002; Wayne et al., 2011). A number of woylie populations demonstrated a large positive response following fox control (Orell 2004). |
| Predation by feral cats (*Felis catus*) | Severe to catastrophic | Large (entire mainland range) | Feral cats are a major predator of woylies, causing severe local decline (James et al., 2002; Priddel & Wheeler 2004; Marlow et al., 2010; Wayne et al., 2011). Cats became the dominant predator of woylies following sustained fox control (Marlow et al., 2015). |
| Inappropriate fire regimes | Severe in presence of foxes and cats | Large (entire mainland range) | Woylies persist through occasional fire. However, in the presence of foxes and feral cats they require dense understorey for shelter. Occasional hot summer and/or autumn fires are necessary to regenerate a dense shrub layer of species such as *Gastrolobium* spp. (poison peas) (Christensen 1980; Wayne et al., 2011). Inappropriate fire regimes, leading to the loss of protective understorey, have negatively impacted the woylie (DEC 2007). |
| Habitat loss and degradation | Severe | Large (entire mainland range) | Direct land clearing for housing, timber, agricultural production and grazing have reduced the effective area of woylie habitat and increased their vulnerability to exotic predators (Yeatman & Groom 2012). Habitat destruction can also be caused by feral pigs (DEC 2007).<br><br>Mining in the jarrah forests of south west Western Australia may also threaten woylies. These areas are under lease for gold and bauxite exploration and mining (Yeatman & Groom 2012). |

| | | | |
|---|---|---|---|
| Competition with introduced herbivores | Low to moderate | Minor | Competition for increasingly limited resources by rabbits *(Oryctolagus cuniculus)* and domestic stock has been a factor in the decline of the woylie, particularly in more arid areas (DEC 2007). |
| Climate change | Moderate | Moderate | Some species of the main food source, fungi, have strong associations with rainfall and temperature (Johnson 1994). Decreases in rainfall could result in a decline in the abundance of fungi and other foods that contribute to the woylie's diet, and may limit suitable habitat (Yeatman & Groom 2012). |
| Introduced disease | Moderate | Moderate | Epizootic disease may have impacted woylies in the past (Abbott 2006, 2008). Disease is likely to be a significant factor in some large declines in population size (Woinarski & Burbidge 2016). There is a high incidence of disease in some subpopulations, which may be making woylies more susceptible to predation (Wayne et al., 2011). |
| Habitat change and resource depletion due to *Phytophthora cinnamomi* (dieback) | Unknown | Minor | *Phytophthora cinnamomi* may reduce the availability of hypogeal fungi (Anderson et al., 2010), the major food of woylies, and may lead to loss of habitat complexity. However, declines of many WA populations have occurred in structurally intact native vegetation and do not appear to be associated with timber harvesting, an activity which spreads phytophthora (Yeatman & Groom 2012). |

**How judged by the Committee in relation to the EPBC Act criteria and regulations**

**Criterion 1. Population size reduction (reduction in total numbers)**
Population reduction (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

**Evidence:**

**Eligible under Criterion 1 A2(b)(e) for listing as Endangered**

In Western Australia, 40 transects are regularly monitored (usually annually) under the Western Shield program (Orell 2004), with woylies having been detected on 23 of these transects. In addition to these sites, 10 transects have been established to monitor reintroduced woylie populations and a further 9 transects, primarily set up for research purposes, can also be used to track changes in woylie populations. In South Australia the island populations are monitored irregularly, and the Venus Bay peninsula population has been monitored about twice per year on average since being released. The re-introduced populations in the fenced reserves of Scotia, Yookamurra and Karakamia are regularly monitored.

Natural populations

The largest natural populations (Perup and Kingston) are found in the Upper Warren region, east of Manjimup. These populations constituted about 85 percent of the species in 1999, but declined by 95 percent between 2000 and 2008 (Wayne et al., 2013). Between 2005 and 2013 these populations remained low but relatively stable at a regional level (Wayne et al., 2013). However, surveys undertaken in 2014 and 2016 showed a significant recovery in the Upper Warren population (Figure 1; Table 2).

As the population shows a change in trend over the last three generation period (9−15 years), the overall reduction over 2001−2016 is calculated by taking a ratio of the average population size at the start of this period (over 2001−2003), to the average population size at the end of this period (over 2014−2016), as per section 4.5.1 of the IUCN Guidelines 2017. This gives an overall population decline in the Upper Warren of approximately 55 percent over the past three generations.

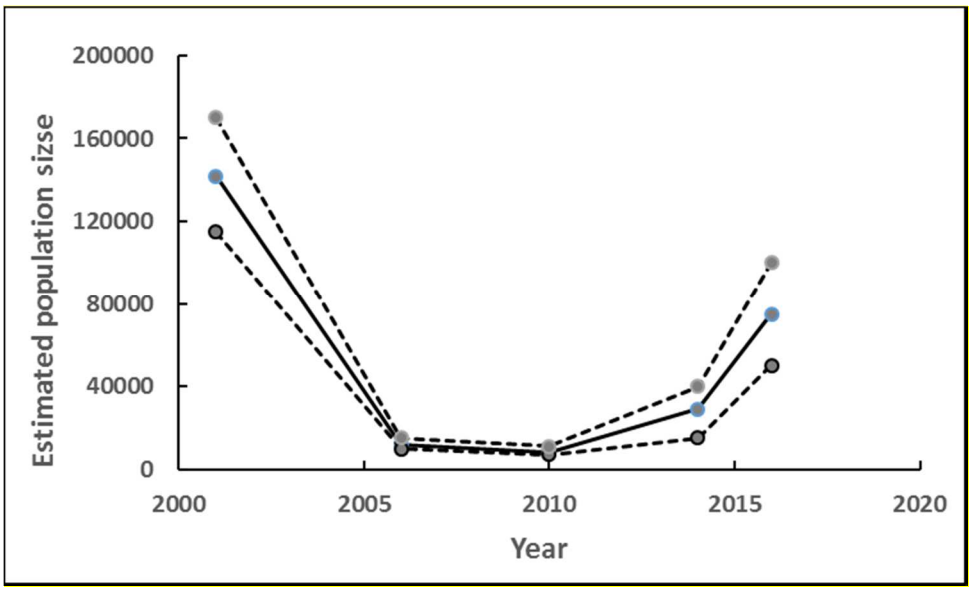


**Figure 1.** Woylie population estimates for the Upper Warren. Dashed lines represent the lower and upper population estimates. Data source: Table 2.

The natural woylie population at Dryandra woodland declined by 92 percent between 1999 and 2006 (Wayne et al., 2013), but has increased since then. Over the past three generations (9−15 years) from 2001 to 2016 the overall population decline at Dryandra has been approximately 61 percent (Table 2).

Since 2010 the other of the original four subpopulations, at Tutanning Nature Reserve, has become functionally extinct (Wayne et al., 2013; Table 2).

Re-introduced subpopulations

Populations have been established in fenced areas from which introduced predators have been eradicated. The fenced populations managed by the Australian Wildlife Conservancy (Karakamia, Yookamurra and Scotia sanctuaries) have remained stable over the past five years (Table 2). Similarly, fenced populations at Perup and Wadderin sanctuaries have increased since they were established in 2010. Individuals from Perup Sanctuary are regularly used to establish and supplement other populations, with average population numbers maintained at around 400 (DPaW pers. comm., 2017).

Re-introductions to Paruna sanctuary failed, most likely because the subpopulation was not fully fenced.

Elsewhere, declines appear to be continuing in several areas (Wayne et al., 2013) such as Boyagin, Batalling and Northern and Central Jarrah, and some subpopulations have become functionally extinct since 2001. The declines are thought to be primarily driven by predation, and increased susceptibility to predation probably due to disease (Wayne et al., 2011; Botero et al., 2013). While populations remain at relatively low levels, their vulnerability to local extinction remains high (Wayne et al., 2013).

The Venus Bay peninsula population in South Australia has declined to very low numbers, due to predation by feral cats and possible depletion of food resources within the fenced peninsula (Woinarski et al., 2014). However, camera, trapping and spotlight data have shown a population increase (although numbers are still low) at Venus Bay over 2014−2017, which is attributed to management efforts to control feral cat predation and reduce competition with other species for food resources (DEWNR pers. comm., 2017).

Table 2 − Woylie population estimates (Wayne et al., 2013, 2017; Woinarski et al., 2014; DPaW pers. comm., 2017, Kanowski pers. comm., 2017)

| State | Location | Extent of occurrence (ha) | 2001 | 2006 | 2010 | 2014 | 2016 |
|---|---|---|---|---|---|---|---|
| WA | Upper Warren* | 110000 | 141953 (115000 - 170000)† | 11776 (10000 - 15000) | 8313 (7000 - 11000) | 29000 (15000 - 40000)†† | 75000 (50000 - 100000)†† |
| WA | Dryandra* | 12192 | 10236 (7000-14000) | 1228 (500-2500) | 2730 (1000-4000) | Persisting, NNE††† | 4000 (2000-7000)†† |
| WA | Boyagin NR* | 4781 | 2529 (1500-4000) | 1265 (500-2000) | 562 (200-1000) | " | Persisting, NNE |
| WA | Batalling* | 8000 | 8494 (5000-10000) | 1156 (700-1500) | 242 (100-400) | " | " |
| WA | Tutanning NR* | 2369 | 438 (200-700) | 199 (100-300) | 199 (100-300) | 0 (0-20), below detection | 0 (0-20), below detection |
| SA | St Peter Is | 3439 | 3000 (1000-7000) | 3000 (1000-7000) | 3000 (1000-7000) | Persisting, NNE | Persisting, NNE |
| SA | Wedge Island | 947 | 1000 (500-2000) | 1000 (500-2000) | 1000 (500-2000) | " | " |
| WA | Middle Warren / Lake Muir | 37239 | 600 (300-1000) | 600 (300-1000) | 600 (300-1000) | " | " |
| WA | Northern & Central Jarrah | 774905 | 2000 (100-5000) | 500 (50-2000) | 400 (50-2000) | " | " |
| WA | Karakamia Sanctuary** | 275 | 500 (400-600) | 500 (400-600) | 500 (400-600) | " | 250 (200-300); stable, previous estimates inflated |
| WA | Sunklands & Pemberton | 89925 | 120 (20-200) | 200 (10-500) | 250 (10-1000) | Pemberton: 0 Below detection; Sunklands: persisting NNE | Pemberton: 0 Below detection; Sunklands: persisting NNE |
| SA | Venus Bay Peninsula | 1100 | 200 (130-300) | 150 (53-350) | 150 (17-400) | Persisting, declined, NNE | Persisting, declined, NNE |
| SA | Yookamurra Sanctuary** | 1100 | 10-20 | 0 | 150 (100-250) | 100 (75-150); stable since 2009 | 100 (75-150); stable since 2009 |
| WA | Julimar NR | 28000 | 10 (2-100) | 120 (40-900) | 130 (40-1000) | Persisting, NNE | Persisting, NNE |
| NSW | Scotia Sanctuary** | 8000 | - | 59 (57-69) | 113 (106-132) | 300 (200-400); stable since 2012 | 300 (200-400); stable since 2012 |
| WA | Avon Valley NP | 4370 | - | 50 (0-200) | 50 (0-200) | 0 Below detection | 0 Below detection |
| WA | Perup Sanctuary | 420 | - | - | 41 introduced | 300 (200-800) | 300 (200-800) |
| WA | Wadderin Sanctuary | 430 | - | - | 35 introduced | Increased, no estimates | Increased, no estimates |
| WA | Whiteman Park Reserve | 4000 | - | - | Trickle introductions | 170-180 | 170-180 |
| SA | Venus Bay "Island A" | 15 | 30 (15-40) | 30 (21-40) | 30 (20-40) | Increased, NNE | Increased, NNE |
| WA | Kalbarri NP | 183000 | 100 (30-120) | 40 (30-50) | 20 (0-50) | 0 Below detection | 0 Below detection |
| WA | North Karlgarin NR | 5622 | - | 40 (20-60) | 10 (0-50) | " | " |
| WA | Walpole/Denmark area | 8988 | 40 (1-100) | 20 (1-100) | 10 (0-50) | " | " |
| WA | Nambung NP | 18400 | - | 50 (0-100) | 0 (0-50) | " | " |
| SA | Lincoln NP | 29000 | 200 (100-300) | 0 (0-30) | 0 (0-50) | " | " |
| WA | Francois Peron NP | 52590 | 50 (20-100) | 10 (1-20) | 0 (0-10) | " | " |
| WA | Paruna Sanctuary | 2000 | 100 | 200 | 0 | " | " |
| WA | Lake Magenta NR | 107810 | 50 | 0 | 0 | " | " |
| **Total species abundance estimate** | | | **171,650** | **22,193** | **18,459** | **39,504** | **86,524** |
| **Lower bound of abundance estimate** | | | **131,468** | **14,533** | **10,893** | **19,317** | **55,117** |
| **Upper bound of abundance estimate** | | | **215,610** | **36,419** | **32,482** | **62,025** | **124,725** |

* Population estimates based on the conversion of capture rates to density estimates derived from Upper Warren.
** Population estimates derived from capture-mark-recapture models from annual live trapping. Estimates for all other locations are based on best available information and expert estimates.
† Parentheses indicate the lower and upper bounds of population estimates: these are derived from 95% confidence intervals for populations marked with * and **, and from expert opinion for other populations.
†† Assumes AOO is comparable over time and the sites monitored in 2014 and 2016 are representative of the Upper Warren and Dryandra area (there may be a bias in favour of those sites that have had greater management focus and higher woylie recoveries).
††† NNE = no new estimates.

## Conclusions

From 2001 to 2010 the total population size of woylies declined significantly, by about 89 percent (Table 2). However, since 2010 the population size has substantially increased, driven mainly by increases in the largest population at Upper Warren, with a variety of trends (increase, decrease, stable or decreased to functionally extinct) recorded at other subpopulations. From 2001 to 2016 there has been an overall decline in the total population by about 50 percent (Table 2). Taking into account the uncertainty in the data and the upper and lower population estimates, this decline may range from 5 percent to 74 percent.

The Committee considers that the species has likely undergone a severe reduction in numbers over three generation lengths (9−15 years for this assessment), equivalent to at least 50 percent, and the causes of the reduction have not ceased. Therefore, the species has met the relevant elements of Criterion 1 to make it eligible for listing as Endangered.

| **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 | | | |

**Evidence:**

**Eligible under Criterion 2 B2(a),(b)(ii,iii,iv) for listing as Endangered**

The historic extent of occurrence (EOO) is estimated to be 1 771 786 km$^2$ (Lomolino & Channell 1995, using information contained in Strahan 1983). The current extent of occurrence is estimated to be 589 674 − 1 420 322 km$^2$, and the area of occupancy estimated to be 468−536 km$^2$, based on the mapping of point records from 1997 to 2017. The lower estimates were derived by excluding records from those populations which may be functionally extinct (population estimates of 0 or below detection in Table 2), and the upper estimates were derived by including records from these populations. 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 2017 (DoEE 2017). The AOO spans the threshold for Vulnerable to Endangered, and so is eligible for listing as Endangered using the precautionary principle.

The woylie's distribution is severely fragmented, which satisfies subcriterion (a). There is a continuing decline in area of occupancy, area of habitat and number of locations (see Criterion 1), which satisfies subcriterion (b)(ii,iii,iv).

The Committee considers that the species' area of occupancy is likely to be restricted, and the geographic distribution is precarious for the survival of the species because the distribution is severely fragmented, and a decline in the area of occupancy, area of habitat and number of locations may be inferred or projected. Therefore, the species has met the relevant elements of Criterion 2 to make it eligible for listing as Endangered.

| **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** |
| (a) (ii) % of mature individuals in one subpopulation = | **90 – 100%** | **95 – 100%** | **100%** |
| (b) Extreme fluctuations in the number of mature individuals | | | |

**Evidence:**

**Not eligible**

The total population size in natural and re-introduced subpopulations in 2017 is estimated to be 55 000 to 125 000 mature individuals (Table 2).

The total number of mature individuals is not considered to be limited. Therefore, the species has not met this required element of this criterion.

| **Criterion 4. Number of mature individuals** | | | |
|---|---|---|---|
| | **Critically Endangered Extremely low** | **Endangered Very Low** | **Vulnerable Low** |
| Number of mature individuals | **< 50** | **< 250** | **< 1,000** |

**Evidence:**

**Not eligible**

The number of mature individuals in natural and re-introduced subpopulations in 2017 is estimated to be 55 000 to 125 000 (Table 2).

The total number of mature individuals is not considered extremely low, very low or low. Therefore, the species has not met this required element of this criterion.

| 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** |

**Evidence:**

**Insufficient data to determine eligibility**

A population viability analysis (PVA) was undertaken by Pacioni (2010), but it did not estimate a probability of extinction in the medium-term future. The PVA estimated the minimum mortality rates necessary for population decline to occur and the minimum viable population size (1000−2000 individuals).

## Conservation actions

### Recovery plan

A recovery plan for *Bettongia penicillata* (woylie) is required, given the past dramatic population declines, ongoing declines or small size of many re-introduced populations, and ongoing threats from fox and feral cat predation.

A recovery plan for the woylie (Yeatman & Groom 2012) was developed by the State of Western Australia, and adopted as a national recovery plan under the EPBC Act in 2012. Actions specified in the recovery plan are:

- Verify the causes of the decline and suppression of recovery and implement remedial actions to address these.
- Minimise predation by introduced foxes and cats at priority sites.
- Maintain or improve the health, genetic diversity, relative value and viability of wild populations.
- Maintain genetic diversity of the insurance captive populations at least at 2012 levels.
- Maintain captive population sizes sufficient to act as source populations for future translocations.
- Undertake targeted translocations as re-introductions (and as introductions where necessary) to achieve an enhanced conservation status for the species.
- Inform and educate the community about, and involve the community in, the recovery actions required to conserve the woylie.

The plan is scheduled to expire on 1 October 2022.

### Primary conservation actions

1. Control the numbers of foxes and feral cats in areas occupied by woylies.
2. Improve understanding of the causes of decline and lack of recovery.
3. Manage and monitor the status of wild and re-introduced populations.
4. Continue to manage insurance populations and undertake targeted wild to wild translocation programs.

**Conservation and management priorities**

Foxes and feral cats are managed in Western Australia and South Australia through various management programs. The private wildlife conservation organisation Australian Wildlife Conservancy (AWC) also have three fenced “introduced predator-free” environments on mainland Australia where woylies have been translocated (Scotia, Yookamurra and Karakamia sanctuaries).

Translocation programs, which aim to increase the distribution of the species, have been undertaken in Western Australia, South Australia and New South Wales. These programs have been undertaken primarily through the relevant state government conservation agencies, but have also involved AWC and other private individuals/organisations. The potential impact of native predators on small re-introduced woylie populations need to be considered, as native predators may reduce the chances of these populations persisting, especially where the ecosystem has been significantly altered to the detriment of woylies (Yeatman & Groom 2012).

Conservation and management priorities are outlined in the table below.

| Theme | Specific actions | Priority |
|---|---|---|
| Active mitigation of threats | Reduce the threat posed by predation by foxes and feral cats, by undertaking integrated fox and cat control. | High |
| | Manage habitat of woylie subpopulations, in order to maximise shelter (i.e. dense understorey) and food requirements. | High |
| Insurance populations | Maintain ‘insurance’ colonies within fenced areas, and ensure genetic diversity. | High |
| Quarantining isolated populations | Prepare and implement biosecurity plans for South Australian islands with woylie subpopulations. | Medium |
| Translocation | Translocate to sites where foxes and cats are absent or effectively controlled, and consider the impacts of possible competition with *Bettongia lesueur* (boodies) when identifying translocation sites (Finlayson 2010; Hayward et al., 2010). | Medium |
| | Manage the long-term genetic diversity of natural and translocated populations (some are genetically depauperate, having been founded from a small group of animals: Pacioni 2010). | Medium |
| Community engagement | Maintain community knowledge of woylie conservation through publications in a wide range of fora and public speaking events. | Medium |
| | Maintain community involvement in woylie conservation through the engagement of private landowners, conservation groups and volunteers in on-ground recovery actions. | Medium |

**Survey and monitoring priorities**

| Theme | Specific actions | Priority |
|---|---|---|
| Survey to determine the status of translocated populations | Confirm the subpopulation status of many former woylie translocations. | Low |
| Establish or enhance monitoring program | Maintain a high level of monitoring of natural and translocated subpopulations. | High |
| Monitor foxes and feral cats | Regularly monitor the abundance of foxes and feral cats to elucidate interactions among predator species and evaluate the effectiveness of control measures. | High |

**Information and research priorities**

| Theme | Specific actions | Priority |
|---|---|---|
| Assess impacts of threats on species | Confirm the causes of declines and reasons for non-recovery in all subpopulations. | High |
| Assess effectiveness of threat mitigation options | Develop methods for effective fox control in the presence of non-target species that remove dried meat baits. | High |
| Undertake research to develop new or enhance existing management mechanisms | Develop broad-scale, targeted feral cat eradication technology that can be used without significant effects on non-target species. | High |

## Recommendations

(i) The Committee recommends that *Bettongia penicillata* retain its current listing status of Endangered in the list referred to in section 178 of the EPBC Act, as there is insufficient evidence to support transferring it to a different category.

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

Threatened Species Scientific Committee

14/09/2017

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