



## Consultation Document on Listing Eligibility and Conservation Actions

### *Bettongia penicillata* (woylie)

You are invited to provide your views and supporting reasons related to:

- 1) the eligibility of *Bettongia penicillata* (woylie) for inclusion on the EPBC Act threatened species list in the Critically Endangered category; and
- 2) the necessary conservation actions for the above species.

Evidence provided by experts, stakeholders and the general public are welcome. Responses can be provided by any interested person.

Anyone may nominate a native species, ecological community or threatening process for listing under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) or for a transfer of an item already on the list to a new listing category. The Threatened Species Scientific Committee (the Committee) undertakes the assessment of species to determine eligibility for inclusion in the list of threatened species and provides its recommendation to the Australian Government Minister for the Environment.

Responses are to be provided in writing either by email to:  
[species.consultation@environment.gov.au](mailto:species.consultation@environment.gov.au)

or by mail to:

The Director  
Marine and Freshwater Species Conservation Section  
Wildlife, Heritage and Marine Division  
Department of the Environment  
PO Box 787  
Canberra ACT 2601

**Responses are required to be submitted by 15 March 2017.**

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## **General background information about listing threatened species**

The Australian Government helps protect species at risk of extinction by listing them as threatened under Part 13 of the EPBC Act. Once listed under the EPBC Act, the species becomes a Matter of National Environmental Significance (MNES) and must be protected from significant impacts through the assessment and approval provisions of the EPBC Act. More information about threatened species is available on the department's website at:

<http://www.environment.gov.au/biodiversity/threatened/index.html>.

Public nominations to list threatened species under the EPBC Act are received annually by the department. In order to determine if a species is eligible for listing as threatened under the EPBC Act, the Threatened Species Scientific Committee (the Committee) undertakes a rigorous scientific assessment of its status to determine if the species is eligible for listing against a set of criteria. These criteria are available on the Department's website at:

<http://www.environment.gov.au/biodiversity/threatened/pubs/guidelines-species.pdf>.

As part of the assessment process, the Committee consults with the public and stakeholders to obtain specific details about the species, as well as advice on what conservation actions might be appropriate. Information provided through the consultation process is considered by the Committee in its assessment. The Committee provides its advice on the assessment (together with comments received) to the Minister regarding the eligibility of the species for listing under a particular category and what conservation actions might be appropriate. The Minister decides to add, or not to add, the species to the list of threatened species under the EPBC Act. More detailed information about the listing process is at:

<http://www.environment.gov.au/biodiversity/threatened/nominations.html>.

To promote the recovery of listed threatened species and ecological communities, conservation advices and where required, recovery plans are made or adopted in accordance with Part 13 of the EPBC Act. Conservation advices provide guidance at the time of listing on known threats and priority recovery actions that can be undertaken at a local and regional level. Recovery plans describe key threats and identify specific recovery actions that can be undertaken to enable recovery activities to occur within a planned and logical national framework. Information about recovery plans is available on the department's website at:

<http://www.environment.gov.au/biodiversity/threatened/recovery.html>.

## **Information about this consultation process**

Responses to this consultation can be provided electronically or in hard copy to the contact addresses provided on Page 1. All responses received will be provided in full to the Committee and then to the Australian Government Minister for the Environment.

In providing comments, please provide references to published data where possible. Should the Committee use the information you provide in formulating its advice, the information will be attributed to you and referenced as a 'personal communication' unless you provide references or otherwise attribute this information (please specify if your organisation requires that this information is attributed to your organisation instead of yourself). The final advice by the Committee will be published on the department's website following the listing decision by the Minister.

Information provided through consultation may be subject to freedom of information legislation and court processes. It is also important to note that under the EPBC Act, the deliberations and recommendations of the Committee are confidential until the Minister has made a final decision on the nomination, unless otherwise determined by the Minister.

# *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 will be 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 clines that terminated in south-eastern Australia (subspecies *penicillata*), south-western Australia (subspecies *ogilbyi*) and northern Queensland (*B. tropica*, originally described as a subspecies of *B. penicillata*).

As there is only one extant subspecies, this assessment also applies to *B. p. ogilbyi*.

## **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. Indigenous names include Woylyer and Karpitchi.

### **Distribution**

The woylie is endemic to Australia. 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 (the remnant of this population now being accepted as *Bettongia tropica*). 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 (excluding *B. tropica*) 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 retreated to the most mesic (mild) parts of its former range after European settlement (Burbidge & McKenzie

1989). By 1970, woylies remained in only four subpopulations in south-west Western Australia: Dryandra Woodland, Tutanning Nature Reserve, and the Upper Warren region (Kingston and Perup).

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 lists in 1998–1999 (Start et al., 1998; TSSC 2009). However, in the 2000s sudden and dramatic declines in population occurred, with the population declining 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 recent study in the wheatbelt region of Western Australia identified that meso-predator release of feral cats following sustained fox control was the most likely cause; predation by feral cats caused most of the mortalities (65%) and was three times the fox predation rate (21%) (Marlow et al., 2015).

The species has been translocated/re-introduced with mixed success to numerous sites in Western Australia, South Australia and New South Wales (NSW), including a number of wildlife sanctuaries and fenced mainland 'islands'. Some of these have failed in the medium- to long-term, including the three in NSW (Priddell & Wheeler 2004; Wayne et al., 2011; Yeatman & Groom 2012).

The woylie currently occurs in around 20 locations in south-west Western Australia and southern South Australia (listed in Woinarski et al., 2014).

### **Relevant Biology/Ecology**

Woylies originally inhabited a wide range of country. In the western deserts, Indigenous people reported that they occupied sand plains and dunes with spinifex (*Triodia* spp.) hummock grassland. The remnant subpopulations in south-western Australia inhabit woodlands and adjacent heaths with a dense understorey of shrubs, particularly *Gastrolobium* spp., which contain monofluoroacetic acid (the compound present as sodium monofluoroacetate in the vertebrate pesticide '1080'). Their diet is largely underground fungi, although it 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).

The woylie rests 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 triodia (in arid coastal areas) (Christensen & Leftwich 1980; Armstrong, pers. comm. 2006 in Freegard 2007). When disturbed from the nest, it will move quickly with head low and tail extended, sometimes colliding with obstacles in its haste to flee.

They 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 1989 in 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).

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 is assumed to be 3–5 years (Woinarski et al., 2014).

## Threats

Table 1 – Threats to the numbat 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 ( <i>Vulpes vulpes</i> )	Severe to catastrophic	Large (entire mainland range)	Foxes are a significant predator of woylies and have caused declines and local extinctions (Kinneary 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 ( <i>Felis catus</i> )	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).
Predation by native animals	Unknown	Minor?	Predation by <i>Morelia</i> sp. (carpet pythons) and <i>Haliaeetus leucogaster</i> (white-breasted sea-eagles) have been implicated in the failed woylie translocation to St Francis Island in South Australia (DEH 2006). <i>Aquila audax</i> (wedgetail eagle) predation contributed to the failed reintroduction to the Flinders Ranges in South Australia (Bellchambers 2001).
Inappropriate fire regimes	Severe in presence of red foxes and cats	Large (entire mainland range)	Woylies are well adapted to 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 <i>Gastrolobium</i> spp. (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	<p>Direct land clearing for housing, timber, agricultural production and grazing have reduced the effective area of woylies' habitat and increases their vulnerability to exotic predators (Yeatman &amp; Groom 2012). Habitat destruction can also be caused by feral pigs (DEC 2007).</p> <p>Mining in the jarrah forests of south west Western Australia may also threaten woylies as these areas are under lease for gold and bauxite exploration and mining (Yeatman &amp; Groom 2012).</p>
Competition with introduced herbivores	Low to moderate?	Minor?	Competition for increasingly limited resources from rabbit ( <i>Oryctolagus cuniculus</i> ) and domestic stock has been a factor in the decline of the woylie, particularly in more arid areas (DEC 2007).
Climate change	Moderate	Moderate	<p>Some species of fungi have strong associations with rainfall and temperature (Johnson 1994). Decreases in rainfall could result in a decline in the abundance of fungi as well as other foods that contribute to the woylie's diet, and may limit suitable habitat (Yeatman &amp; Groom 2012).</p>
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 (Wayne 2008). There is a high incidence of disease in some subpopulations, which may be making woylies more susceptible to predation (Wayne et al., 2011).
Loss of genetic diversity	Low to moderate	Minor: some translocated subpopulations	Some translocated subpopulations are genetically depauperate, having been founded from a small groups of animals (Pacioni 2010). The interaction of predation and inbreeding may be a significant threat (Pacioni 2010).
Habitat change and resource depletion due to <i>Phytophthora cinnamomi</i> (dieback)	Unknown	Minor	<i>Phytophthora cinnamomi</i> may reduce the availability of hypogaeal fungi (Anderson et al., 2010), the major food of woylies, and may lead to loss of habitat complexity. However, recent declines of many WA populations have occurred in structurally intact native vegetation and do not appear to be associated with forest harvesting (Yeatman & Groom 2012).

Competition with congeners	Unknown	Localised: Mainland islands	Finlayson (2010) and Hayward et al. (2010) suggest there may be some competition between woylies and boodies ( <i>Bettongia lesueur</i> ). 172 woylies declined rapidly to 20 following reintroduction in the presence of boodies in the first fenced area at Scotia Sanctuary, while they have done well in an adjacent fenced area at Scotia in the absence of boodies.
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## **Assessment of available information in relation to the EPBC Act Criteria and Regulations**

<b>Criterion 1. Population size reduction (reduction in total numbers)</b> Population reduction (measured over the longer of 10 years or 3 generations) based on any of A1 to A4			
	<b>Critically Endangered Very severe reduction</b>	<b>Endangered Severe reduction</b>	<b>Vulnerable Substantial reduction</b>
<b>A1</b>	<b>≥ 90%</b>	<b>≥ 70%</b>	<b>≥ 50%</b>
<b>A2, A3, A4</b>	<b>≥ 80%</b>	<b>≥ 50%</b>	<b>≥ 30%</b>
<div> <div> 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. </div> <div> based on any of the following </div> <div> (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 </div> </div>			

### **Evidence:**

In Western Western Shield program (Orel 2004 Australia, 40 transects are regularly monitored (usually annually) under the), 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, also capture woylies. 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.

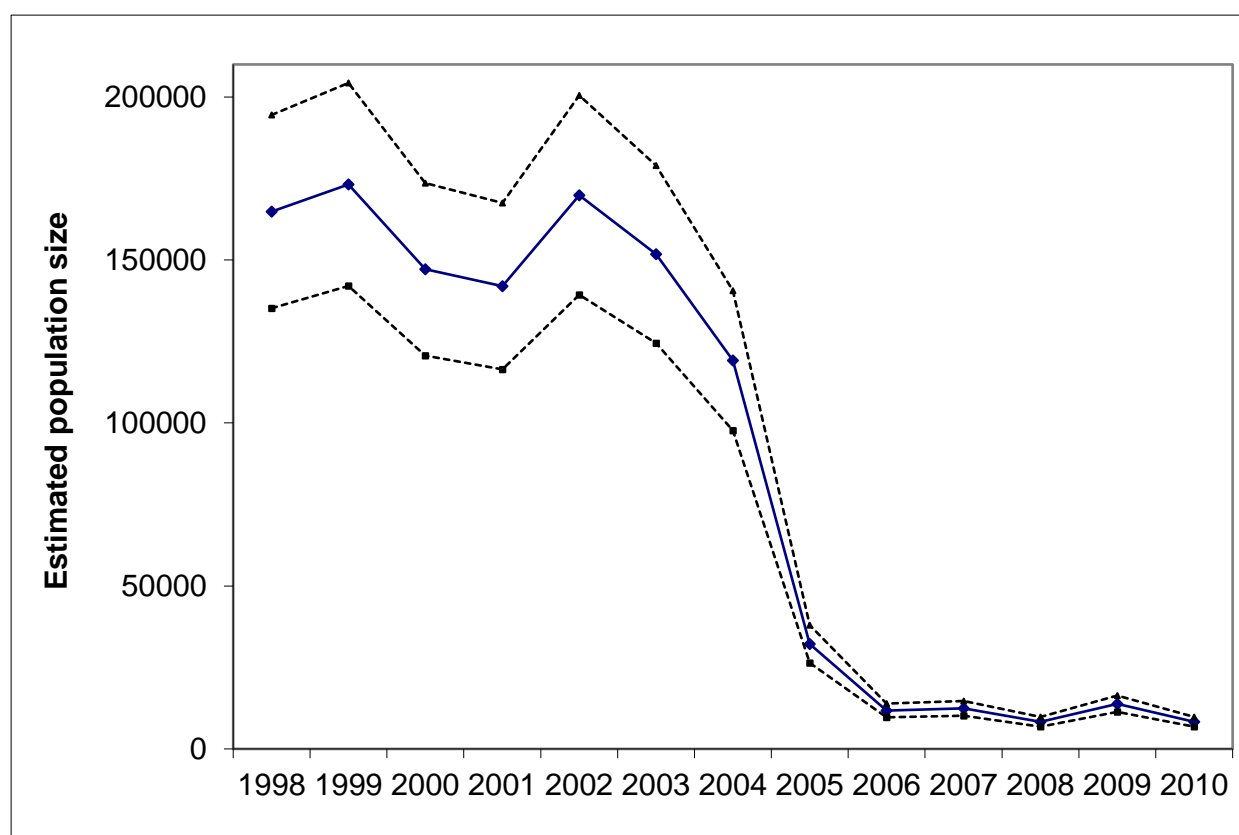
The largest natural populations (Perup and Kingston) are found in the Upper Warren region, east of Manjimup. These populations constituted about 85% of the species in 1999, but declined by 95% between 2000 and 2008 (Fig.1; Wayne et al., 2013). Between 2005 and 2013 these populations have remained low but relatively stable at a regional level (Adrian et al., 2013).

The natural woylie population at Dryandra woodland declined by 92% between 1999 and 2006 (Wayne et al., 2013).

Forty-one woylies were translocated to the Perup Sanctuary mainland island in October-December 2010. The population size has been increasing since, and was estimated at 300-400 individuals in mid-late 2013 (Adrian et al., 2013).

The total population in natural and reintroduced subpopulations in 2010 was around 18 000 (11 000 to 32 000). Since then one of the original four subpopulations, at Tutanning Nature Reserve, has been extirpated (Adrian et al., 2013) and the Venus Bay peninsula population in South Australia has crashed to almost undetectable levels due to predation by feral cats and possible depletion of food resources within the fenced peninsula (Woinarski et al., 2014). Declines are continuing in several areas (Adrian et al., 2013), with the declines thought to be primarily driven by predation, and increased susceptibility to predation probably due to disease (Wayne et al., 2011, 2015; Botero et al., 2013). While populations remain at relatively low levels, their vulnerability to local extinction remains high (Adrian et al., 2013).

Over the past three generations (12 years) from 2003 to 2015, based on population trends in the Upper Warren, the total population size of woylies has likely declined by at least 80% (Fig. 1).



**Fig. 1.** Woylie population estimate for the Upper Warren (core 110 000 ha only), based on a conversion of median capture rate to density ( $R^2 = 0.90$ ). The lower and upper 95% confidence intervals for the regression co-efficient for the relationship between capture rate and density are presented as dashed lines (Wayne et al., 2013).

The data presented above appear to demonstrate that the species is **eligible for listing as Critically Endangered** under Criterion 1 (A2)(b)(e). However, the purpose of this consultation document is to elicit additional information to better understand the species' status. This conclusion should therefore be considered to be tentative at this stage, as it may be changed as a result of responses to this consultation process.

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 km <sup>2</sup>	< 5,000 km <sup>2</sup>	< 20,000 km <sup>2</sup>
B2. Area of occupancy (AOO)	< 10 km <sup>2</sup>	< 500 km <sup>2</sup>	< 2,000 km <sup>2</sup>
AND at least 2 of the following 3 conditions indicating distribution is precarious for survival:			
(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:

The historic extent of occurrence (EOO) is estimated at 1 771 786 km<sup>2</sup> (Lomolino & Channell 1995, using information contained in Strahan 1983). In 2006, the EOO was estimated to be 18 300 km<sup>2</sup> (Freegard 2007), which is about 1 percent of its former range. While these estimates are based on a variety of methods, they show that the EOO has reduced considerably.

In 2012 the extent of occurrence, excluding translocated populations, was estimated to be less than 20,000 km<sup>2</sup> (Woinarski et al., 2014), which meets the threshold for Vulnerable. The woylie's distribution is severely fragmented, which satisfies condition (a). There is a continuing decline in area of occupancy, area of habitat and number of mature individuals (see Criterion 1), which satisfies condition (b)(ii,iv,v).

The data presented above appear to demonstrate that the species is **eligible for listing as Vulnerable** under this criterion. However, the purpose of this consultation document is to elicit additional information to better understand the species' status. This conclusion should therefore be considered to be tentative at this stage, as it may be changed as a result of responses to this consultation process.

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:

The total population in natural and reintroduced subpopulations in 2010 was estimated to be 11 000 to 32 000. Since then it is likely that one of the original four subpopulations, at Tutanning Nature Reserve, no longer survives (N. Marlow, pers. comm., cited in Woinarski et al., 2014), and the Venus Bay peninsula population in South Australia has crashed to almost undetectable levels due to predation by feral cats and possible depletion of food resources within the fenced peninsula.

The data presented above appear to be insufficient to demonstrate if the species is eligible for listing under this criterion. However, the purpose of this consultation document is to elicit additional information to better understand the species' status. This conclusion should therefore be considered to be tentative at this stage, as it may be changed as a result of responses to this consultation process.

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

### Evidence:

The number of mature individuals in natural and reintroduced subpopulations in 2010 was estimated to be 11 000 to 32 000 (Woinarski et al., 2014).

The data presented above appear to demonstrate the species is not eligible for listing under this criterion. However, the purpose of this consultation document is to elicit additional information to better understand the species' status. This conclusion should therefore be considered to be tentative at this stage, as it may be changed as a result of responses to this consultation process.

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:

A population viability analysis undertaken by Pacioni (2010) estimated that the minimum mortality rates necessary for population decline to occur are 28 percent for juveniles and subadults and 22 percent for adults, per a 91 day time period. The PVA also estimated the minimum viable population size to be 1000–2000 individuals. It did not estimate a probability of extinction in the medium-term future.

The data presented above appear to demonstrate the species is not eligible for listing under this criterion. However, the purpose of this consultation document is to elicit additional information to better understand the species' status. This conclusion should therefore be considered to be tentative at this stage, as it may be changed as a result of responses to this consultation process.

## **Conservation Actions**

### **Recovery Plan**

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 in 2022 and has not yet been reviewed.

### **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 undertake captive breeding and targeted 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 fenced “introduced predator-free” environments on mainland Australia where woylies have been translocated.

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 also involving AWC and other private individuals/organisations.

Recommended conservation and management actions are outlined in the table below.

<b>Theme</b>	<b>Specific actions</b>	<b>Priority</b>
Active mitigation of threats	Eliminate the threat posed by predation by foxes and feral cats, by undertaking integrated fox and cat control	High
	Manage the conservation estate containing woylie subpopulations, in order to maximise shelter (i.e. dense understorey) and food requirements	High
	Genetically augment the South Australian populations	Medium

Captive breeding	Maintain captive colonies of major genetic lines or mix genetic lines; maintain 'insurance' colonies within fenced areas	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	Medium
Community engagement	Maintain community involvement in, and knowledge of, woylie conservation	Medium

### Survey and Monitoring priorities

Theme	Specific actions	Priority
Survey to better define distribution	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
Resolve taxonomic uncertainties	Resolve <i>Bettongia penicillata</i> / <i>B. tropica</i> taxonomy	Low
Assess habitat requirements	N/a	
Assess diet, life history	N/a	
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
Assess competition between woylies and boodies	Phd research is being conducted on this topic at Scotia and Yookamurra.	Low

## **References cited in the advice**

- Abbott, I. (2001). Aboriginal names of mammal species in south-west Western Australia. *CALMScience* 3, 433-486.
- Abbott, I. (2002). Origin and spread of the cat, *Felis catus*, on mainland Australia, with a discussion on the magnitude of its early impact on native fauna. *Wildlife Research* 29, 51–74.
- Abbott, I. (2006). Mammalian faunal collapse in Western Australia, 1875-1925: the hypothesised role of epizootic disease and a conceptual model of its origin, introduction, transmission, and spread. *Australian Zoologist* 33, 530-561.
- Abbott, I. (2008). The spread of the cat, *Felis catus*, in Australia: re-examination of the current conceptual model with additional information. *Conservation Science Western Australia* 7, 1–17.
- Anderson, P., Brundrett, M., Grierson, P., & Robinson, R. (2010). Impact of severe forest dieback caused by *Phytophthora cinnamomi* on macrofungal diversity in the northern jarrah forest of Western Australia. *Forest Ecology and Management* 259, 1033-1040.
- Bellchambers, K. (2000). Brush-tailed Bettong re-introduction and monitoring, and Bushbird, Emu and Native Pine monitoring. Report to the Department of Environment and Heritage, South Australia for the Bounceback Program, Flinders Ranges National Park. 39pp.
- Bellchambers K (2001). Brush-tailed bettong re-introduction and monitoring in the Flinders Ranges National Park and bushbird and emu monitoring in the Flinders Ranges and Gammon Ranges National Parks. Research consultancy prepared for the Department of Environment and Heritage, South Australia.
- Bellchambers, K. (2002). Trial re-introduction of the brush-tailed bettong into Flinders Ranges National Park. In Bounceback, Flinders Ranges, final project report, December 2002. Department of Environment and Heritage, South Australia.
- Botero, A., Thompson, C., Peacock, C., Clodec, P. L., Nicholls, P., Wayne, A., Lymbery, A. J., & Thompson, R. C. A. (2013). Trypanosomes genetic diversity, polyparasitism and the population decline of the critically endangered Australian marsupial, the brush-tailed bettong or woylie (*Bettongia penicillata*). *International Journal for Parasitology: Parasites and Wildlife* 2, 77-89.
- Burbidge, A. A., & Fuller, P. J. (1984). Finding out about desert mammals. *SWANS* 14, 9-13.
- Burbidge, A. A., Johnson, K. A., Fuller, P. J., & Southgate, R. I. (1988). Aboriginal knowledge of the mammals of the central deserts of Australia. *Australian Wildlife Research* 15, 9-39.
- Burbidge, A. A., & McKenzie, N. L. (1989). Patterns in the modern decline of Western Australia's vertebrate fauna: causes and conservation implications. *Biological Conservation* 50, 143-198.
- Burbidge, A. A., McKenzie, N. L., Brennan, K. E. C., Woinarski, J. C. Z., Dickman, C. R., Baynes, A., Gordon, G., Menkhorst, P. W., & Robinson, A. C. (2009). Conservation status and biogeography of Australia's terrestrial mammals. *Australian Journal of Zoology* 56, 411-422.
- Calaby, J. H., & Richardson, B. J. (1988). Potoroidae. In *Zoological catalogue of Australia. Volume 5. Mammalia* (ed D. W. Walton), pp. 53-59. Australian Government Publishing Service, Canberra.

- Christensen, P. E. S. (1980). The biology of *Bettongia penicillata* (Gray 1837) and *Macropus eugenii* (Demarest 1817) in relation to fire. Bulletin No. 91, Forests Department of Western Australia.
- Christensen, P., & Leftwich, T. (1980). Observations on the nest-building habits of the brush-tailed rat-kangaroo or woylie (*Bettongia penicillata*). *Journal of the Royal Society of Western Australia* 63, 33-38.
- Delroy, L. B., Earl, J., Radbone, I., Robinson, A. C., & Hewett, M. (1986). The breeding and re-establishment of the Brush-tailed Bettong, *Bettongia penicillata*, in South-Australia. *Australian Wildlife Research* 13, 387-396.
- Department of Environment and Conservation (DEC) (2007). Records held in DEC's Threatened Fauna Database and rare fauna files. Department of Environment and Conservation, Perth.
- Department for Environment and Heritage (DEH) (2006). Island Parks of Western Eyre Peninsula Management Plan, Adelaide, South Australia.
- de Tores, P., & Start, A. N. (2008). Woylie *Bettongia penicillata*. In *The Mammals of Australia*. Third Edition. (Eds S. Van Dyck & R. Strahan), pp. 291-292. Reed New Holland, Chatswood.
- Facey, A. (1981). *A Fortunate Life*. Fremantle Arts Centre Press, Fremantle.
- Finlayson, G. R. (2010). The reintroduction of medium-sized marsupials in western New South Wales. School of Biological Sciences, University of Sydney.
- Ford, C., & Hogg, C. (Eds). (2012). *Australasian species management program: regional census and plan*. 22nd Edition. Zoo and Aquarium Association, Sydney.
- Freegard, C. (2007). *Bettongia penicillata ogilbyi* - nomination of a Western Australian species for listing as threatened, change of status or delisting. Department of Conservation and Land Management, Perth.
- Freegard, C. (2008). Draft Woylie (*Bettongia penicillata ogilbyi*) Interim Recovery Plan 2008-2013. Department of Environment and Conservation, Perth.
- Garkaklis, M. J., Bradley, J. S., & Wooller, R.D. (1998). The effects of Woylie (*Bettongia penicillata*) foraging on soil water repellency and water infiltration in heavy textured soils in southwestern Australia. *Austral Ecology* 23, 492-496.
- Groom, C. (2010). Justification for continued conservation efforts following the delisting of a threatened species: a case study of the woylie, *Bettongia penicillata ogilbyi* (Marsupialia : Potoroidae). *Wildlife Research* 37, 183-193.
- Hall, G. P., Nelson, L., Storr, R., & Robinson, A. C. (1991). Recovery plan for the Brush-tailed Bettong or Woylie (*Bettongia penicillata*). Report submitted to Australian National Parks and Wildlife Service, Endangered Species Program Project No. 149. Department of Conservation and Land Management, Perth.
- Hayward, M. W., Legge, S., Parsons, B. C., Page, M. J., Herman, K., & Mulder, E. (2010). Woylie *Bettongia penicillata* (Potoroidae: Marsupialia) reintroduction as part of the Australian Wildlife Conservancy's endangered species recovery programme at Scotia Sanctuary, far western New South Wales, Australia. In *Global re-introduction perspectives: 2010: additional case studies from around the globe* (Ed P. S. Soorae.), pp. 202-207. IUCN Species Survival Commission Reintroduction Specialist Group: Abu Dhabi, UAE.

- Hide, A. (2006). Survival and dispersal of the threatened woylie *Bettongia penicillata* after translocation. Honours thesis. The University of Western Australia, Nedlands.
- James, H., Acharya, A.B., Taylor, J.A., & Freak, M.J. (2002). A case of bitten bettongs. *The Journal of Forensic Odonto-Stomatology* 20(1), 10-12.
- Johnson, C. (1994). Fruiting of hypogeous fungi in dry sclerophyll forest in Tasmania, Australia: seasonal variation and annual production. *Mycological Research* 98, 1173-1182.
- Katarapko Community Action Group (2001). Unpublished project report; Brush-tailed Bettong Introduction to Katarapko Island. 11 pp.
- Keynes, T. (1989). Some notes on keeping and breeding of the brush-tailed bettong. Accessed 27 June 2012. Available on the internet at: <http://www.marsupialsociety.org/btbettong.html>.
- Kinnear, J., Sumner, N. R., & Onus, M. L. (2002). The red fox in Australia—an exotic predator turned biocontrol agent. *Biological Conservation* 108, 335-359.
- Leftwich, T. D. (1983). The reintroduction of the woylie (*Bettongia penicillata*) into a forest area. Forests Department, Western Australia, Perth.
- Lomolino, M. V., & Channell, B. (1995). Splendid isolation: patterns of geographic range collapse in endangered mammals. *Journal of Mammalogy* 76(2), 335-347.
- Marlow, N.J. Williams, A., Thomas, N., Macmahon, B., & Lawson, J. (2010). Science division annual research activity report and management implications. Department of Environment and Conservation, Western Australia.
- Marlow, N.J., Thomas, N.D., Williams, A.E., Macmahon, B., Lawson, J., Hitchen, Y., Angus, J. & Berry, O. (2015). Cats (*Felis catus*) are more abundant and are the dominant predator of woylies (*Bettongia penicillata*) after sustained fox (*Vulpes vulpes*) control. *Australian Journal of Zoology* 63, 18-27. Available on the internet at: <http://www.publish.csiro.au/?paper=ZO14024>
- Maxwell, S., Burbidge, A. A., & Morris, K. (1996). *The 1996 action plan for Australian marsupials and monotremes*. Wildlife Australia, Canberra.
- Murphy, M. T., Garkalis, M. J., & Hardy, G. (2005). Seed caching by woylies *Bettongia penicillata* can increase sandalwood *Santalum spicatum* regeneration in Western Australia. *Austral Ecology* 30, 747-755.
- Nelson, L. S., Storr, R. F., & Robinson, A. C. (1992). Plan of management for the woylie, *Bettongia penicillata* Gray 1837 (Marsupialia, Potoroidae) in South Australia. Department of Environment and Planning, South Australia.
- Orell, P. (2004). Fauna monitoring and staff training: Western Shield review—February 2003. *Conservation Science Western Australia* 5, 51–95.
- Pacioni, C. (2010). The population and epidemiological dynamics associated with the recent decline of woylies (*Bettongia penicillata*) in Australia. Ph.D. Thesis, The University of Western Australia, Nedlands.
- Pacioni, C., Wayne, A. F., & Spencer P. B. S. (2011). Effects of habitat fragmentation on population structure and long-distance gene flow in an endangered marsupial: the woylie. *Journal of Zoology* 283, 98–107.
- Priddel, D., and Wheeler, R. (2004). An experimental translocation of brush-tailed bettongs (*Bettongia penicillata*) to western New South Wales. *Wildlife Research* 31, 421-432.

- Roache, M. (2011). *The action plan for threatened Australian macropods*. WWF-Australia, Sydney.
- Robinson, T., Canty, P., Mooney, T., & Rudduck, P. (1996). *South Australia's offshore islands*. Department of Environment and Natural Resources, Adelaide.
- Sampson, J. C. (1971). The biology of *Bettongia penicillata* (Gray, 1837). Ph.D. thesis, The University of Western Australia, Nedlands.
- Serventy, V. (1970). *Dryandra: the story of an Australian forest*. AH and AW Reed, Sydney.
- Start, A. N., Burbidge, A. A., & Armstrong, D. (1995). Woylie recovery plan. Wildlife Management Program No. 16. Western Australian Department of Conservation and Land Management and South Australian Department of Environment and Natural Resources. Perth.
- Start, A. N., Burbidge, A. A., & Armstrong, D. (1998). A review of the conservation status of the woylie, *Bettongia penicillata ogilbyi* (Marsupialia: Potoroidae) using IUCN criteria. *CALMScience* 2, 277-289.
- Strahan, R. (1983). *The Australian Museum Complete Book of Australian Mammals*. Angus and Robertson, London, United Kingdom.
- Threatened Species Scientific Committee (TSSC) (2009). *Commonwealth Listing Advice on Bettongia penicillata ogilbyi (Woylie)*. Department of the Environment, Water, Heritage and the Arts. Available on the internet at: <http://www.environment.gov.au/biodiversity/threatened/species/pubs/66844-listing-advice.pdf>.
- Troughton, E. (1973). *Furred Animals of Australia*. Angus and Robertson, Brisbane.
- Wayne A (2008). Progress Report of the Woylie Conservation Research Project. Diagnosis of recent woylie (*Bettongia penicillata ogilbyi*) declines in southwestern Australia. Department of Environment and Conservation, Perth WA.
- Wayne, A., Maxwell, M., Nicholls, P., Pacioni, C., Reiss, A., Smith, A., Thompson, A., Vellios, C., Ward, C., Wayne, J., Wilson, I., & Williams, M. (2011). The Woylie conservation research project: investigating the cause(s) of woylie declines in the Upper Warren region. Progress Report December 2011. Department of Environment and Conservation, Perth.
- Wayne, A. F., Maxwell, M., Ward, C., Vellios, C., Ward, B., Liddel, G. L., Wilson, I., Wayne, J. C., & Williams, M. R. (2013). The importance of getting the numbers right: quantifying the rapid and substantial decline of an abundant marsupial, *Bettongia penicillata*. *Wildlife Research* 40, 169-183.
- Wayne, A.F., Maxwell, M.A., Ward, C.G., Vellios, C.V., Wilson, I.J., & Dawson, K.E. (2013). Woylie Conservation and Research Project: Progress Report 2010-2013. Available on the Internet at: [http://www.dpaw.wa.gov.au/images/Wayne\\_et\\_al\\_2013\\_WCRP\\_Report\\_2010\\_13\\_Feb\\_14\\_doc.pdf](http://www.dpaw.wa.gov.au/images/Wayne_et_al_2013_WCRP_Report_2010_13_Feb_14_doc.pdf)
- Wayne, A. F., Maxwell, M. A., Ward, C. G., Vellios, C. V., Wilson, I., Wayne, J.C., & Williams, M. R. (2015). Sudden and rapid decline of the abundant marsupial *Bettongia penicillata* in Australia. *Oryx* 49, 175-185.
- Woinarski, J. C. Z., Burbidge, A. A., & Harrison, P. L. (2014). *The action plan for Australian mammals 2012*. CSIRO Publishing, Collingwood.



Yeatman, G. (2010). Demographic changes of a woylie (*Bettongia penicillata*) population: a response to increasing density and climate drying? B.Sc. (Hons) Thesis, The University of Western Australia, Nedlands.

Yeatman, G. J., & Groom, C. J. (2012). National recovery plan for the Woylie *Bettongia penicillata*. Wildlife Management Program No. 51. Department of Environment and Conservation, Perth.

#### **Other sources cited in the advice**

AnAge (2012). The animal aging and longevity database.  
<http://genomics.senescence.info/species/>

Wayne, A., Friend, T., Burbidge, A., Morris, K., & van Weenen, J. (2008). *Bettongia penicillata*. In *IUCN red list of threatened species*. Version 2012.1. Available on the internet at: [www.iucnredlist.org](http://www.iucnredlist.org).

## **Consultation questions**

1. Do you agree with the current taxonomic position of the Australian Faunal Directory for this taxon (as identified in the draft conservation advice)?
2. Can you provide any additional references, information or estimates on longevity, age of maturity, average life span and generation length?
3. Has the survey effort for this taxon been adequate to determine its national distribution and adult population size?
4. Do you accept the estimate provided in the nomination for the current population size of the taxon?
5. For any population with which you are familiar, do you agree with the population estimate provided? If not, are you able to provide a plausible estimate based on your own knowledge? If so, please provide in the form:
  - Lower bound (estimated minimum):
  - Upper bound (estimated maximum):
  - Best Estimate:
  - Estimated level of Confidence: %
6. Can you provide any additional data, not contained in the current nomination, on declines in population numbers over the past or next 10 years or 3 generations, whichever is the longer?
7. Is the distribution as described in the nomination valid? Can you provide an estimate of the current geographic distribution (extent of occurrence or area of occupancy in km<sup>2</sup>) of this taxon?
8. Has this geographic distribution declined and if so by how much and over what period of time?
9. Do you agree that the taxon is eligible for inclusion on the threatened species list, in the category listed in the nomination?
10. Do you agree that the threats listed are correct and that their effects on the taxon are significant?
11. To what degree are the identified threats likely to impact on the taxon in the future?
12. Can you provide additional or alternative information on threats, past, current or potential that may adversely affect this taxon at any stage of its life cycle?
13. In seeking to facilitate the recovery of this taxon, can you provide management advice for the following:
  - What individuals or organisations are currently, or need to be, involved in planning to abate threats and any other relevant planning issues?
  - What threats are impacting on different populations, how variable are the threats and what is the relative importance of the different populations?
  - What recovery actions are currently in place, and can you suggest other actions that would help recover the taxon? Please provide evidence and background information.
14. Can you provide additional data or information relevant to this assessment?
15. Can you advise as to whether this species is of cultural significance to Indigenous Australians?