The Minister approved this conservation advice and included this species in the Vulnerable category, effective from 5 May 2016

Conservation Advice

Macroderma gigas

ghost bat

*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 have 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 Advice*s. *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 *Macroderma gigas* (Dobson 1880).

Macroderma is a monotypic genus endemic to Australia. There is a possibility that *Macroderma* exists in Papua New Guinea (Filewood 1983), but this has never been confirmed. The ghost bat is the largest species in the family and comprises several disjunct subpopulations across northern Australia.

A second subspecies from the Kimberley, *M. gigas saturata*, was described by Douglas (1962) using diagnoses based on pelage and skin colour. However, it has now been synonymised with *M. gigas* (Koopman 1984; Simmons 2005). Studies of morphological and genetic variation across the species' distribution found clinal variation in size (northern ghost bats were smaller; Hand & York 1990), and a high degree of population subdivision with greater connectedness amongst colonies in northern subpopulations (Worthington Wilmer et al., 1994, 1999). However, these findings were not suggested as a basis for subspecific taxonomic distinctness, and no subspecies are recognised.

Summary of assessment

Conservation status

Vulnerable: Criterion 1 A2(b)(c)(d), A3(b)(c)(d), A4(b)(c)(d) and Criterion 3 C1

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 list *Macroderma gigas.*

Public Consultation

Notice of the proposed amendment and a consultation document was made available for public comment for 40 business days between 30 September 2015 and 25 November 2015. Any comments received that were relevant to the survival of the species were considered by the Committee as part of the assessment process.

Species Information

Description

The ghost bat is the largest microchiropteran bat in Australia, with a head and body length of 10−13 cm and a forearm length of 10−11 cm. It is Australia's only carnivorous bat. Its fur is light to dark grey above and paler below. It has long ears which are joined together, large eyes, a simple noseleaf and no tail (Richards et al., 2008).

Distribution

Fossil data show that the ghost bat was once distributed widely over much of Australia except Victoria and Tasmania, including the arid zone, but contracted northwards during the Holocene period (Molnar et al., 1984; Churchill & Helman 1990). A study that combined information from ancient DNA obtained from remains in extinct southern populations, newly-generated and existing genetic data from extant northern populations, and ecological niche modelling based on past and present climatic conditions (Thomson et al., 2012), suggested that the ghost bat expanded southwards during periods of higher humidity (interglacials) and contracted northwards in response to increasing aridity (e.g. preceding the last glacial maximum). The combined analyses support previous statements that the ghost bat is a geographically relictual species in southern, arid landscapes, present only because caves provide suitable roost microclimates.

At the time of European settlement, arid zone subpopulations remained. Since the arrival of Europeans, ghost bats have contracted further northwards, with much of their arid zone distribution disappearing in the past few decades (Molnar et al., 1984; Churchill & Helman 1990). Burbidge et al. (1988) reported that western desert Aboriginal people stated that ghost bats only ever occurred in a few favourable areas and that they were still present. However, searches of several central Australian sites where they once occurred have since failed to locate any (Churchill & Helman 1990). The last arid zone specimen was collected in 1961 (Butler 1962). The major range contraction from central Australia happened more than three generations (24 years) ago.

The species' current range is discontinuous, with geographically disjunct colonies occurring in the Pilbara (Armstrong & Anstee 2000; McKenzie & Bullen 2009), Kimberley (including several islands; McKenzie & Bullen 2012), northern Northern Territory (including Groote Eylandt), the Gulf of Carpentaria (Australian Wildlife Conservancy 2010), coastal and near coastal eastern Queensland from Cape York to near Rockhampton (Richards et al., 2008), and western Queensland (including Riversleigh and Cammoweal districts; Bullen pers. comm., 2015). Burbidge et al. (2009), using modern, historical and subfossil data, found that the ghost bat occurred in 37 of Australia's 85 bioregions, and that it was extinct in 12. Only 14 breeding sites are currently known (Worthington Wilmer 2012).

Populations are highly structured, being genetically distinct at both regional and local scales (Worthington Wilmer et al., 1994, 1999; Armstrong et al., in prep). Populations at the southern limits of the species' range are geographically isolated and separated by a minimum distance of 300 km. This geographic isolation is reflected in the genetic data with populations at Mt Etna, Cape Hillsborough, and Camooweal in Queensland, and the Pilbara in Western Australia, being highly divergent genetically, and implies virtually no movement of individuals between these sites (Worthington Wilmer et al., 1999). Populations within the Northern Territory and far north Queensland are also highly distinct from each other and other population centres (Worthington Wilmer et al., 1999), while the Kimberley bats are distinct from all other Australian populations with genetic structure evident in the Kimberley populations (Worthington Wilmer 1996).

Population genetic studies indicate a high degree of female philopatry (remaining in, or returning to, an individual's birthplace) at natal roosts based on mitochondrial DNA markers; gene flow within regions mediated by male movements was also suggested from nuclear microsatellite markers (Worthington Wilmer et al., 1994, 1999). Northern groups had higher heterozygosity and less marked phylogeographic structure than southern groups, which was interpreted to be a

consequence of the limited availability and greater separation of roost sites with suitable microclimates in more arid areas. Recent studies that have built on the work by Worthington Wilmer et al. (1994, 1999), by adding individuals from the Pilbara and Kimberley regions, have also highlighted the distinctness of these two subpopulations, high female philopatry, and gene flow within regions arising from male movements (K. Armstrong et al., pers. comm., cited in Woinarski et al., 2014). Losses of sites containing breeding females have the potential to reduce the area of occupancy and population size significantly.

Relevant Biology/Ecology

Ghost bats are the largest microchiropteran bat in Australia and the second largest in the world, weighing up to 150 g and having a wingspan of 60 cm. They currently occupy habitats ranging from the arid Pilbara to tropical savanna woodlands and rainforests. During the daytime they roost in caves, rock crevices and old mines. Roost sites used permanently are generally deep natural caves or disused mines with a relatively stable temperature of 23°−28°C and a moderate to high relative humidity of 50−100 percent (Pettigrew et al., 1986; Churchill & Helman 1990; Churchill 1991; Armstrong & Anstee 2000; J. Toop unpublished data). They are carnivores, with a broad diet comprising small mammals including other bats, birds, reptiles, frogs and large insects (Pettigrew et al., 1986; Schulz 1986; Boles 1999; J. Toop unpublished data). The proportion of food items in the diet varies with availability. At Pine Creek in the Northern Territory, diet predominantly comprised birds as large as the dollarbird (*Eurystomus orientalis*), which weighs 125−140 g (Schulz, 1986; Pettigrew et al., 1986). At Mount Etna, diet has at times been mostly large insects, while at other times the prey included vertebrates such as birds, bats, rats and mice (J. Toop, unpublished data).

The ghost bat has a surface foraging strategy with two modes. It perches in vegetation to ambush passing prey (either on the ground or in the air), and it also gleans surfaces such as the ground while in flight. Its echolocation calls show wide variation (McKenzie & Bullen 2009). Tidemann et al. (1985) found that foraging areas were centred, on average, 1.9 km from the daytime roost. The mean size of foraging areas was 61 ha and tagged bats generally returned to the same areas each night. Hunting behaviour within foraging areas consisted of observation at vantage points with brief sallies to capture prey (mostly insects on the ground), though hawking of flying insects was also observed. Vantage points were changed about every 15 minutes during foraging periods, and the mean distance between them was 360 m. Foraging areas were not exclusive; there was overlap between the ranges of several tagged individuals, and in one case an area was used by 20 bats.

Hoyle et al. (2001), who studied the southern-most known colony in Queensland, found that female bats gave birth to a single young in late spring, but only 40 percent (22–70%, 95% confidence interval (CI)) of females bred in their second year, increasing to 93 percent (87–97%, 95% CI) for females ≥ 2 years old. Sixty-five percent of juveniles captured were female. Annual adult survival ranged 0.57–0.77 for females and 0.43–0.66 for males, and was lowest over winter–spring and greatest in autumn–winter. Juvenile survival for the first year ranged 0.35–0.46 for females and 0.29–0.42 for males. Adult survival varied among seasons, and was negatively associated with rainfall but not associated with temperature apart from being lower in late winter. Poor survival may result from the inferior daytime roosts that bats must use if water seepage forces them to leave their normal roosts. Although these age-specific rates of fecundity and survival suggested a declining population, mark-recapture estimates of the population trend indicated stability over the study period. Counts at daytime roosts also suggested a population decline, but were considered unreliable because of an increasing tendency of bats to avoid detection. At Mount Etna, Toop (1985) found that pregnant females congregated in the warmest caves and gave birth over a month commencing in mid-October. As caves became warmer as summer progressed, some mothers shifted the young to other caves. Juvenile bats commenced flying at seven weeks with all young capable of flight by the end of January.

Ghost bats move between a number of caves seasonally or as dictated by weather conditions, and require a range of cave sites (Hutson et al., 2001). Most breeding sites appear to require multiple entranced caves (L. Hall pers. comm., cited in McKenzie & Hall 2008). Ghost bats disperse widely when not breeding, but concentrate in a relatively few roost sites when

breeding. Few of these sites are known (Richards et al., 2008; Worthington Wilmer 2012), and most are not protected or managed.

Roost sites include caves, rock crevices and disused mine adits. In the Hamersley Range in the Pilbara, preferred roosting habitat appears to be caves beneath bluffs of low rounded hills composed of Marra Mamba geology, and larger hills of Brockman Iron Formation; in the eastern Pilbara, caves beneath bluffs composed of Gorge Creek Group geology and granite rockpiles are preferred (Armstrong & Anstee 2000). The species' persistence in the arid Pilbara depends on the physiologically benign day roosts found deep underground in humid, temperature-stable caves (Leitner & Nelson 1967; Hall et al., 1997; Armstrong & Anstee 2000; McKenzie & Bullen 2009).

Ghost bats are easily disturbed when roosting. Young may be dislodged by adults in rapid take-offs (J. Toop, unpublished data) and may not return to the roost site (K. Armstrong pers. comm., cited in Woinarski et al., 2014). This makes counting individuals at roost sites difficult and repeated counts may be unreliable (Armstrong 2010). Such susceptibility to disturbance also threatens the viability of roosts with unregulated human visitation, including surveys which target caves and may inadvertently flush individuals into daylight.

Females breed at an age of two to three years (Hoyle et al., 2001). Longevity in the wild is unknown, but is likely to be somewhat less than the maximum 22.6 years in captivity (AnAge 2012). Generation time is assumed to be 8 years (Woinarski et al., 2014).

Threats

The key threat to the ghost bat is habitat loss and degradation due to mining activities (McKenzie & Hall 2008; Qld DEHP 2015). The species' slow reproductive rate, and the lack of suitable habitat which restricts its movement, renders it vulnerable to threats and localised extinctions (Qld DEHP 2015). The genetic isolation of each subpopulation suggests areas are unlikely to be recolonised if a local extinction occurs (Qld DEHP 2015).

Threats to the ghost bat are outlined in the table below (Woinarski et al., 2014).

Threat factor	Consequence rating	Extent over which threat may operate	Evidence base
Habitat loss (destruction of, or disturbance to, roost sites and nearby areas) due to mining	Severe	Moderate	Mt Etna and the surrounding area contain breeding sites, some of which have been destroyed; declines were reported at Mt Etna following mining; Mt Etna is now protected in a national park and visited by tourists (Worthington Wilmer 2012). Mount Consider cave west of Cairns has been destroyed; other sites are still vulnerable; limestone mining is a threat in Cooktown. Many Pilbara roosts are vulnerable to iron ore mining and the deterioration and disturbance of old underground gold and copper mines.

Disturbance of (human visitation at) breeding sites	Moderate-severe	Moderate	Ghost bats are easily disturbed and may abandon sites where disturbance occurs (K. Armstrong pers. comm., cited in Woinarski et al., 2014). Minor disturbances by approaching vehicles and people may result in bats moving to alternative roost sites (Bullen pers. comm., 2015). Larger disturbances by recreational cavers or ecologists entering caves may cause the loss of pups and/or abandonment of roost sites (Bullen pers. comm., 2015).
Modification to foraging habitat	Moderate	Moderate	Vegetation simplification can impact on foraging strategies and productive riparian sites. Foraging bats search for prey from vantage points in trees before making short flights to capture prey (Tidemann et al.,1985). To persist in an area, small colonies require a group of caves/shelters that provide alternative day and night roost sites, and a gully or gorge system that opens onto a plain or riparian line that provides good foraging opportunities, typically less than 5 km from the diurnal roost site (Bullen pers. comm., 2015). Livestock grazing, fire and weed encroachment can degrade habitat (Qld DEHP 2015); some population declines could be attributable to prey lost through habitat modification by fire and livestock (Duncan et al., 1999).
Collision with fences, especially those with barbed wire	Moderate	Moderate	Ghost bats have low fecundity and survival (Hoyle et al., 2001). They often fly at about fence height and substantial numbers are known to be killed when colliding with fencing wire (Armstrong & Anstee 2000; McKenzie & Bullen 2009). A single fence near a colony can effectively remove all of these individuals given enough time, and has been observed in the Pilbara (Armstrong & Anstee 2000; Armstrong pers. comm., 2015).
Collapse or reworking of old mine adits	Minor-moderate	Minor-moderate	Many of the known nursery roosts are in old mine workings that are collapsing, flooding or subject to disturbance (Hall et al., 1997; Armstrong 2001); e.g. the Pine Creek colony roosts in an adit that is in danger of collapse (Richards et al., 2008).
Contamination by mining residue at roost sites	Moderate	Moderate	Several roosting sites in old mines have high levels of pollutants that may reduce rates of survival or reproduction.

Disease	Unknown	Unknown	A possible herpes-type virus appears to be affecting the Mt Etna population, but the pathology is yet to be confirmed (J. Augusteyn pers. comm., cited in Woinarski et al., 2014).
Poisoning by cane toads	Severe	Moderate (may become Moderate-Entire)	There is evidence of ghost bats preying upon cane toads in Kakadu NP; bats have been found dead with chewed toads in their throats (White & Bullen pers. comm., cited in Qld DEHP 2015). There has been a significant reduction in numbers of ghost bats in the Riversleigh district, western Queensland, apparently due to the consumption of cane toads (Bullen pers. comm., 2015). Genetic work indicates that the ghost bat is unable to tolerate bufotoxins (Shine et al., in review, cited in Armstrong pers. comm., 2015).
Competition for prey with foxes and feral cats	Unknown	Unknown	Some population declines could be attributable to competition for prey with foxes and feral cats (Duncan et al., 1999).

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)(c)(d), A3(b)(c)(d), A4(b)(c)(d) for listing as Vulnerable

Woinarski et al. (2014) estimate the population size of the ghost bat to be fewer than 10 000 mature individuals, with an estimated continuing decline of greater than 10 percent in 24 years (three generations). There is evidence of significant declines in some parts of the species' distribution.

Western Australia

Ghost bats occur in the Pilbara and the Kimberley, with abandoned mine adits (horizontal tunnels) comprising a significant proportion of the known roost sites (Woinarski et al., 2014). The presence of mines may have allowed the species to extend its range and expand its population size in the past (e.g. Worthington Wilmer et al., 1999). However, many disused mines are now collapsing or being open cut and reworked (Armstrong 2001, 2011; WA DPaW 2015).

There is a possibility of population decline following the loss of some root sites in the Pilbara (Armstrong pers. comm., 2015). Most of the population in the Pilbara region is known from six historical mine workings: Bamboo Creek, Bulletin, Comet, Klondyke Queen, Lalla Rookh and All Nations mines (Armstrong pers comm., 2015). In the past these populations probably had over 1000 individuals (Armstrong & Anstee 2000). Two of them (All Nations and Bulletin mine) appear to have now disappeared; the remaining four mines show evidence of collapse, flooding and human intrusion and are part of active mineral exploration leases, and may have decreased in size (Armstrong pers comm., 2015). The other smaller colonies are found in caves and relatively small adits, with colony sizes typically less than 10 (Armstrong and Anstee 2000; Armstrong pers. comm., 2015).

In the Pilbara, most known breeding sites of the ghost bat are confined to underground gold/copper mines that are now collapsing or being open cut, and to caves in banded ironstone strata that may be mined out over the next 30−50 years. On current trends, most of its Pilbara roost sites may be destroyed over the next 30 years (Woinarski et al., 2014). Numbers are likely to decline by over 30 percent in Western Australia in the future with local extinction in areas such as the central and eastern Hamersley Range, with the extent of occupancy likely to decline by over 10 000 km^2 (Bullen pers. comm., 2015). However, barbed wire fences are being replaced in crucial areas and breeding sites are being identified for protection (WA DPaW 2015), which may reduce the current rate of decline.

The Kimberley colonies (containing approximately two-thirds of the state's ghost bat population) are likely to be relatively stable, as little mining or habitat destruction occurs in the region, with cane toads the main threat. However, limited surveys have been undertaken in the Kimberley (WA DPaW 2015), and it is unclear to what extent cane toads will affect these populations in the future if cane toads advance further into the Kimberley.

Northern Territory

Populations in Kakadu National Park are believed to have declined by more than 90 percent since the arrival of cane toads in 2001. No formal surveys in Kakadu National Park were undertaken prior to 2014, but informal surveys and approximate counts were undertaken by rangers, with the most reliable undertaken in the 1980s (Table 1). Surveys undertaken in 2014-2015 show that many of the largest roosting areas are now abandoned, including the largest colonial site at Ngarradji Warde Djobkeng (Table 1; White et al., in prep). The remaining colonies are reduced and in areas remote from waterholes (A. White unpublished data, cited in Qld DEHP 2015).

Table 1. Population estimates for major ghost bat sites in Kakadu National Park. Other sites not listed are small, day roosting sites. (A. White pers. comm., 2016.)

Location	1984-1986 estimates	2014-2015 surveys	Known breeding site
Ngarraddj Warde Djobknong	800+	0	Yes
Nawurlandja	30-50	1	Yes
Rockholes Mine	30-50	0	No
Blue Rocks Caves (Caves 1-6)	50-100	18	Yes
Hawk Dreaming (Caves 1-3)	50+	22	Yes
Jabiru Dreaming	30	0	No
Riflefish Dreaming	20	0	No

Counts have been undertaken at Pungalina, now owned and managed by the Australian Wildlife Conservancy, from 2005 to 2012. The population appeared to be stable throughout this period. A few ghost bat carcasses were found in 2012; it is unclear whether these can be attributable to cane toad poisoning as cane toads arrived in Pungalina several years before 2005 (N. White pers. comm., 2015b).

Milne & Pavey (2011) considered the species to be relatively common and secure in the wet dry tropics of the Northern Territory. However, the largest known breeding site at Kohinoor Adit in Pine Creek (Pettigrew et al., 1986) faces threats from unregulated human visitation, potential mine collapse and possibly contaminated water (Woinarski et al., 2014) and may be in decline (WA DPaW 2015; Qld DEHP 2015). Grant et al. (2010) summarised the counts at Kohinoor Adit (Table 2). A count was also undertaken in 2013 using a thermal video camera and missile tracking software (Armstrong pers. comm., 2015). Sampling precision has varied with methods used, and counts vary depending upon the season of count and breeding stage (Woinarski et al., 2014). However, the counts suggest that numbers may have declined by more than 30 percent over the past 24 years (three generations).

Table 2. Counts of ghost bats at various dates at the largest known breeding site, Kohinoor Adit.

Date	Count
July 1981	300
May 1983	445
June 1984	780
May 1985	1100
April 1987	1300
February 1988	1400
August 1988	1300
January 1990	1500
July 2010	564
December 2013	550

Queensland

The Queensland subpopulations are located in 4−5 highly disjunct localities. Data are available for four of the five main colonies, and all are in decline (Table 3) (Qld DEHP 2015). No information is available for the Mitchell Palmer colony. Limited information is available for the remaining colonies, but most are considered to be small with fewer than 50 individuals; it is possible the entire Queensland population is in decline but further information is required to confirm this (Qld DEHP 2015). The Boodjamulla (Lawn Hill and Riversleigh) population is now thought to be extinct (A. White pers. comm., cited in Qld DEHP 2015).

Table 3. Data for 4 Queensland subpopulations, showing decline (Qld DEHP 2015, with additions).

Subpopulation	Previous estimate	Recent estimate
Mt Etna	170 (2011/12 estimate; Worthington Wilmer 2012)	40 (number of bats seen in 2013; Augusteyn et al., in prep)
Cape Hillsborough	180 (2011/12 estimate; Worthington Wilmer 2012)	50 (inferred from multiple cave visits 2011-2014; Cali pers. comm., cited in Qld DEHP 2015)
Camooweal	160−180 (2013 estimate; Qld DEHP 2015)	50−100 (Armstrong & White pers. comm., cited in Qld DEHP 2015)
Kings Plains	167 (1995 direct count estimate by Les Hall; Hughes pers. comm., 2015)	108 (2014 direct count estimate by Peter Bannink; Hughes pers. comm., 2015)

At Mount Etna only 26 individuals were captured over several months, whereas Worthington Wilmer (1996) caught 25 individual bats over two nights in 1993 at a similar time of year, at the same site and using the same methodology (Woinarski et al., 2014). Preliminary results from a genetic coalescence study suggested an effective population size of 15−30 depending on the method used (J. Augusteyn pers. comm., cited in Woinarski et al., 2014). The average age of the Mt Etna colony is around five years, with each pair of successful breeding individuals only just achieving population replacement (Toop & Davies, unpublished). Recent trapping of the Cape Hillsborough wintering roost also indicates that the wintering population is declining when compared with numbers caught and recorded from these caves from the mid 1970s to early 1990s (M. Cali pers. comm., cited in Woinarski et al., 2014). The Mt Etna population, and probably the Cape Hillsborough population also, is genetically isolated and too small to survive as a viable population, and will likely become extinct (N. White pers. comm., 2015a).

Conclusions

A summary of past and projected declines over the past 24 years (1992-2016), based on the data provided above, are summarised in Table 4.

Table 4. Summary of above data

Population	Past population size	Current population size	Past decline	Decline over a 24 year period (may include past and present)
Pilbara, WA	Likely >2000 based on current population estimate and past decline	1300-2000	Likely >30% as 2 out of 6 sites have disappeared, with decline in the others	>>30% (inferred from threats)
Kimberley, WA	3000-4000	3000-4000	0% (inferred)	>10% (inferred from future threats and the impacts of cane toads in Kakadu)
Kakadu, NT (subset: 7 populations)	1010-1100	41	96-96%	90% (ongoing threats)
Kohinoor Adit, NT	1500	550	63%	60% (ongoing threats)
Queensland (subset: 4 populations)	677-697	248-298	56-64%	60% (ongoing threats)
TOTAL	8187-9297	5139-6889	16-45%	>30% (ongoing threats)

The Committee considers that the species has undergone a substantial reduction in numbers over three generation lengths (24 years for this assessment), equivalent to at least 30 percent and the reduction has not ceased, and the cause has not ceased. Therefore, the species has met the relevant elements of Criterion 1 to make it eligible for listing as Vulnerable.

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:

Not eligible

The extent of occurrence is estimated at 3 989 300 km^2, and the area of occupancy estimated at 1104 km^2. These figures are based on the mapping of point records from 1996 to 2016, obtained from state governments, museums, CSIRO and the Australian Wildlife Conservancy. 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 (DotE 2016). Mapped point records from 1966 to 1996, which give an EOO of 5 649 306 km^2 and an AOO of 1952 km^2 (DotE 2016), show that the historical distribution was much larger.

The EOO is currently stable in the Pilbara but continues to decline behind the cane toad front in the Kimberley, Northern Territory and Queensland (Bullen pers. comm., 2015). The area of occupancy is continuing to decline (Woinarski et al., 2014). However, the ghost bat occurs at more than 10 locations and does not suffer extreme fluctuations (Woinarski et al., 2014). Populations are fragmented, but not considered severely fragmented (other than in Queensland) as there is likely to be interchange among colonies within, although not between, other parts of the range (McKenzie & Hall 2008).

Following assessment of the data the Committee has determined that the geographic distribution is very restricted, and there is a continuing decline in the population and distribution. However, the distribution is not severely fragmented and there is no evidence of extreme fluctuations. Therefore, the species has not met the required elements of this criterion.

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			

Evidence:

Eligible under Criterion 3 C1 for listing as Vulnerable

Although the ghost bat can be counted readily when it leaves caves and mine roosts after dusk because of its large size and pale colour, there are no robust measures of abundance across its full range. Monitoring of colony size has been conducted mostly on an ad-hoc basis over the past three decades at certain large colonies, and data have been collected from some colonies over several years (Woinarski et al., 2014).

McKenzie and Hall (2008) estimated the total population size to be 7000−9000 individuals, with differences amongst the regional subpopulations. Worthington Wilmer (2012) stated that, based on known colonies and without projections for unknown colonies, counts for Australia ranged from 4000 to 6000 individuals (750−850 in Queensland, 2500−3500 in the Northern Territory and about 1500 in Western Australia). Available population data are presented below.

Western Australia

Hall et al. (1997) reported the following subpopulation size data from mines in the Pilbara:

- Comet: 35 (26 April 1981); 37+ (14 October 1993); 100+ (19 July 1996)
- Klondyke: 40 (1 May 1981); 98+ (24 April 1994); 20+ (14 July 1994); 40+ (18 July 1995); counts by Armstrong (2010) varied between 107 and 366 for the period 12 June 2011 to 5 July 2001
- Bulletin: 406 (23 April 1994); 200+ (18 July 1995).

Armstrong and Anstee (2000) estimated 1200 individuals to occur in the Pilbara. However, surveys for environmental impact assessments have discovered several larger colonies in the past decade (Armstrong 2011) and activities associated with mining have had an undocumented effect at several known roost sites (K. Armstrong pers. comm., cited in Woinarski et al., 2014). McKenzie and Bullen (2009) commented on the apparent commonness of the ghost bat after recording ghost bats at 21 of their 24 survey areas in the Pilbara, and in all four Pilbara sub-regions, though diurnal roosting and colony sizes were not examined explicitly and their acoustic detection method was not optimal for this species.

Surveys since 2009 indicate that the Pilbara populations exist in two regions: the Chichester subregion with a population of approximately 1500, and the Hamersley subregion with a population of approximately 350 (Bullen pers. comm., 2015). In the Chichester subregion (eastern Pilbara), ghost bats occur mostly in medium to large groups in historical underground mines, most of which appear to be breeding sites; ghost bats are spread across the Hamersley Range in a large number of small groups of less than 20 (Armstrong & Anstee 2000; Bullen pers. comm., 2015). The current population size in the Pilbara is estimated to be 1300−1900 individuals (Armstrong pers. comm., 2015) or 1500−2000 individuals (Bullen pers. comm., 2015).

In the Kimberley a population size of around 3000−4000 individuals has been inferred (McKenzie & Hall, 2008). The species has been recorded on six Kimberley Islands which, at the date of this assessment, were last visited in February 2010 (McKenzie & Bullen 2012).

The total population size in Western Australia (comprising the Pilbara and Kimberley) is therefore estimated at 4300−6000 individuals.

Queensland

In Queensland the population size has been estimated at fewer than 1000 individuals (Woinarski et al., 2014), and possibly as low as 470−680 individuals excluding the Calvert River / Pungalina population on the Northern Territory/Queensland border (Table 5) (Qld DEHP 2015).

Table 5. Population estimates for Queensland (Qld DEHP 2015).

Subpopulation	Most recent population estimate
Mt Etna	40
Cape Hillsborough	50
Camooweal	50-100
Kings Plains (Cooktown)	108
Mt Isa/Cloncurry	50
Mitchell Palmer	50
Cape Melville/ McIlwraith	20
Blackbraes/Chudleigh	50
Wet Tropics	50

On Cape York Peninsula, breeding sites are known at Mitchell-Palmer limestone and Kings Plains station, with a suspected site near the Iron Range (Reardon et al*.,* 2010). Other available Queensland population estimates are of 150 at Girringun-Gugu Badhun West of Ingham / Cardwell and 500 at Kuku Nyungkul – Kuku Bubogun south of Cooktown (C. Clague pers. comm., cited in Woinarski et al., 2014).

Northern Territory

The total population in the Northern Territory is estimated to be 2500−3500 individuals, based on counts at known colonies (Worthington Wilmer 2012). The population in Pungalina, just over the border from Queensland, is estimated to be 100 from counts undertaken from 2005 to 2012 (N. White pers. comm., 2015b). The population at Kohinoor Adit is estimated to be 550 (Armstrong pers. comm., 2015), and at Kakadu around 100 (A. White pers. comm., 2016).

Conclusions

Woinarski et al. (2014) estimate the total population size to be fewer than 10 000 individuals, based on a combination of counts of colony size at some roost sites plus calculations based on area of occupancy. There is a projected continuing decline of greater than 10 percent in a future 24 year (three generation) period (Woinarski et al., 2014; also see Criterion 1). It is unknown

whether the number of mature individuals in each subpopulation is less than 1000, as colony sizes in the Kimberley are unknown.

The Committee considers that the estimated total number of mature individuals of this species is limited, and the population is likely to decline at a substantial rate of 10 percent in the next three generations due to a decline in extent of occurrence, area of occupancy, habitat and number of locations. Therefore, the species has met the relevant elements of Criterion 3 to make it eligible for listing as Vulnerable.

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 population size is estimated at 7000−9000 mature individuals (McKenzie & Hall 2008); see information provided under Criterion 3.

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:

Not eligible

Population viability analysis has not been undertaken.

Conservation Actions

Recovery Plan

The Committee recommends that there should be a recovery plan for the ghost bat. Stopping decline and supporting recovery of the species is complex, due to the requirement for a high level of planning to abate the threats, a high level of support by key stakeholders, and a high level of prioritisation. Existing mechanisms are not adequate to address these needs.

Primary Conservation Actions

1. Protect roost sites from mining, human disturbance and collapse.
2. Replace the top strands of barbed wire in fences near roost sites with single-strand wire.

Conservation and Management Actions

The majority of known colonies occur in protected areas (e.g. national parks or heritage listed mine sites) (McKenzie & Hall 2008). However, some breeding sites, for example in the Pilbara, are not protected and no formal monitoring plan has been implemented (Armstrong & Anstee 2000; K. Armstrong pers. comm., cited in McKenzie & Hall 2008). Current management activities include protection of some breeding sites, a captive breeding programme, long-term population studies and monitoring in Queensland, and population studies in Western Australia (McKenzie & Hall 2008; WA DPaW 2015).

Bullen (pers. comm., 2015) notes that while some roosting sites are protected, extended habitat retention at ridge and creek line scales surrounding roosting sites is needed, as well as protection of these areas from disturbance (including from airborne dust clouds which affect the bats' eyesight and hunting success, and burying of preferred foraging habitat under stored overburden).

Recommended management actions are outlined in the table below (Woinarski et al., 2014).

Theme	Specific actions	Priority
Active mitigation of threats	Protect land with significant colonies.	High
	In barbed wire fences close to roost sites, replace the top strand with single-strand wire, and put a metal disc (around 10x10cm) between the top and second strands.	High
	Protect roost sites and surrounding foraging areas from disturbance, including the loss of habitat quality due to changes to fire and grazing regimes.	Medium
	Where appropriate, modify roost site areas to reduce risks of collapse, and ensure mine-adits that are known roost sites for ghost bats are maintained following the cessation of mining activities.	Medium
Captive breeding	N/a	
Quarantining isolated populations	N/a	
Translocation	N/a	
Community engagement	Educate people not to disturb roost sites.	Medium
Reduce disturbance of roost sites	Where there are known roosts in proximity to mining or other activities, ensure disturbance is minimised by undertaking environmental assessment, considering alternative locations for works and impact mitigation measures.	High

Survey and monitoring priorities

Theme	Specific actions	Priority
Survey to better define distribution	Collate and review all information on Pilbara roost sites, and identify banded-ironstone areas in all parts of the region that are planned for future mining or may be quarantined from mining.	High
	Additional surveys, especially to locate breeding sites, are required in remote parts of the Pilbara, Kimberley and Northern Territory.	High
	Assess population size (and significance) of all known subpopulations.	Medium-high
Establish or enhance monitoring program	Monitor populations at key sites and where impacts from mining are occurring or likely.	High

	Develop cost-effective monitoring protocols (e.g. thermal tracking software) at a set of standardised sites that contain most of the known population.	Medium

Information and research priorities

Theme	Specific actions	Priority
Assess impacts of threats on species	Assess impacts of disturbance of breeding sites, and identify appropriate buffer zones for specific activities around roost sites so mining and other activities do not lead to abandonment.	High
Assess effectiveness of threat mitigation options	Assess options for establishment of new/artificial roost sites (as a last resort only), and mitigation options to reduce impacts of mining. Evaluate the success of such actions.	Medium
Resolve taxonomic uncertainties	N/a	
Assess habitat requirements	Assess seasonal access to foraging areas in the Pilbara remote from major roosts.	Medium
Assess diet, life history	Assess proximity to roosts of foraging habitats used by lactating females compared to other adults.	Medium

Recommendations

(i) The Committee recommends that the list referred to in section 178 of the EPBC Act be amended by **including** in the list in the Vulnerable category:

Macroderma gigas

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

Threatened Species Scientific Committee

2/3/2016

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